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Proposed Solid Waste System for Rural Areas of Brookings County, South Dakota

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PROPOSED SOLID WASTE SYSTEM FOR RURAL AREAS OF BROOKINGS COUNTY, SOUTH DAKOTA

BY

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PROPOSED SOLID WASTE
SYSTEM FOR RURAL AREAS
OF BROOKINGS COUNTY, SOUTH DAKOTA

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Advisor — Date

Head, Civil Engineering Department — Date

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INTRODUCTION

The need for an adequate solid waste collection and disposal system in South Dakota has existed for a long time. Until very recently there were no Statewide laws or regulations concerning the problems of solid waste. Most of the communities in South Dakota, with the exception of the largest cities, ignored the problem of solid waste and maintained very limited facilities. In most cases the system consisted of an open dump with no provisions for solid waste collection. Collection was the responsibility of the individual. Several cities operated a "minimum" sanitary landfill, which resembled an open dump more than a true sanitary landfill in operation. Small towns and rural residents disposed of their refuse by indiscriminant dumping, thereby creating a serious health problem as well as a blight on the community. This type of disposal resulted in open dumps being located wherever it was convenient for the hauler to unload.

With the enactment of the South Dakota Solid Waste Act of 1972, statewide standards were established and a timetable for compliance set forth. In addition, the State issued an Air Pollution Control Regulation in January, 1972, which banned open burning in city dumps.

The State Department of Environmental Protection has stated that its goal is to have all solid waste generated

in the State of South Dakota, stored, collected and disposed of in a manner which does not cause environmental degradation, potential health hazards, or nuisances to the citizens of South Dakota or its visitors(1). It is the intent to provide efficient economical solid waste management systems throughout the entire State. In addition to properly managed solid waste disposal sites, it is also desired that efficient, routine collection systems be provided in all communities wherever the population is sufficient to support such a collection system(1).

The objectives of this study are:

1. to define the solid waste problem as it exists in Brookings County;
2. to study the solid waste problem for a rural area;
3. to estimate the quantity of solid waste involved in Brookings County, both urban and rural;
4. to propose a possible solution to the solid waste collection and disposal problem in a rural area, specifically Brookings County;
5. to estimate the cost of a rural solid waste collection system.

INFORMATION ABOUT BROOKINGS COUNTY

Location and Description

Brookings County lies along the eastern boundary of South Dakota about midway between the northern and southern border. The County is about 34 miles east to west and 24 miles north to south, having an area of 512,640 acres or 801 square miles. The County is served by several major highways: US 77 and Interstate 29 bisect the County north and south; and US 14 traverses the County east to west. The County is also served by several hard-surfaced local roads as well as numerous all-weather graveled roads.

The County is divided into 23 townships. The only major city is Brookings, which is the sixth largest in the State. There are seven small towns in the County; Volga, Aurora, Elkton, White, Bruce, Bushnell and Sinai.

The rural area of Brookings County is mainly farm land. In 1950, farms occupied 490,151 acres with about 79% in cropland, 18% in pasture, and the remainder used for miscellaneous purposes(2). The production of livestock and livestock grains is the main enterprise of the farms in the County.

Topography and Climate

Brookings County lies entirely on the Prairie Coteau at elevations of 1600 to 1800 feet above sea level. This section is comprised entirely of glacial drift underlain by marine cretaceous strata(2). The Big Sioux River flows from north to south across the County and its bottom land and tributaries make up a large area of the County. This area is nearly level and contains soils that are intermittently to constantly wet. Stream flow is negligible except in spring when runoff occurs. An area of fairly level terraces exist along the east side of the Big Sioux River valley. Beyond this area lie the sloping uplands and broad ridges that are well-drained and without depressions. All of this area drains into the Big Sioux River. The western part of the County is gently undulating to rolling with round top hills and depressions. The northeast corner of the County is also rolling and contains some closed depressions. The northwest corner and southwest corner contain some very poorly-drained land and marshes(2).

The climate of Brookings County is continental(2). Because it is located a great distance from large bodies of water, temperature extremes are common, with the region influenced by air masses from northern regions as well as from the Gulf of Mexico. Both seasonal and daily temperature fluctuations are great; however, neither temperature

nor precipitation fluctuates as much as in central and western South Dakota(2).

Spring is moist, cool and windy; summer is hot and sunny; autumn is dry, cool and sunny and winter is cold and long. The precipitation of spring, autumn and winter is generally frontal while summer precipitation is mainly from thunderstorms. Frontal precipitation is usually of low intensity and generally covers the entire County while the thunderstorms can be very localized.

Temperatures can vary from above 100 degrees in summer to 20 degrees below zero or lower in the winter. The average date of the last frost is May 17 and the average day of the first frost is September 21(3). The average annual precipitation is 20.59 inches, of which 16.46 inches falls during the growing season(3). Seasonal snowfall averages 24 inches(3). Strong winds often accompany snowfall causing drifts. Snow cover in excess of one inch depth exists for about 63 days per year. The prevailing winds average ten miles per hour from the south in the summer and eleven to twelve miles per hour from the northwest in winter(3). Winds of forty miles per hour and over occur occasionally with cold fronts or thunderstorms(3).

Population

The population of Brookings County can be divided into three parts for the purpose of this study: the City of

Brookings; the population of the seven small towns of the County; and the rural population. The County map, Figure 1, shows the location of the towns as well as the rural townships. A brief discussion of each is desirable because the numbers and growth patterns of each vary considerably.

Table 1: Population of Brookings County by Year(4).

Year	Population
1877	250
1880	4,965
1890	10,000
1900	12,561
1910	14,178
1920	16,119
1930	16,847
1940	16,560
1950	17,851
1960	20,046
1970	22,158

The City of Brookings has had a very constant growth since its founding until at present it is the sixth largest city in the State. This growth can be traced to the location as a trade center, and by the presence of South Dakota State University. The population has grown from 2346 in 1900 to 13,717 in 1970. This community should continue to grow.

The seven small towns in the County have had varied growth patterns, but as a whole reveal a steady population.

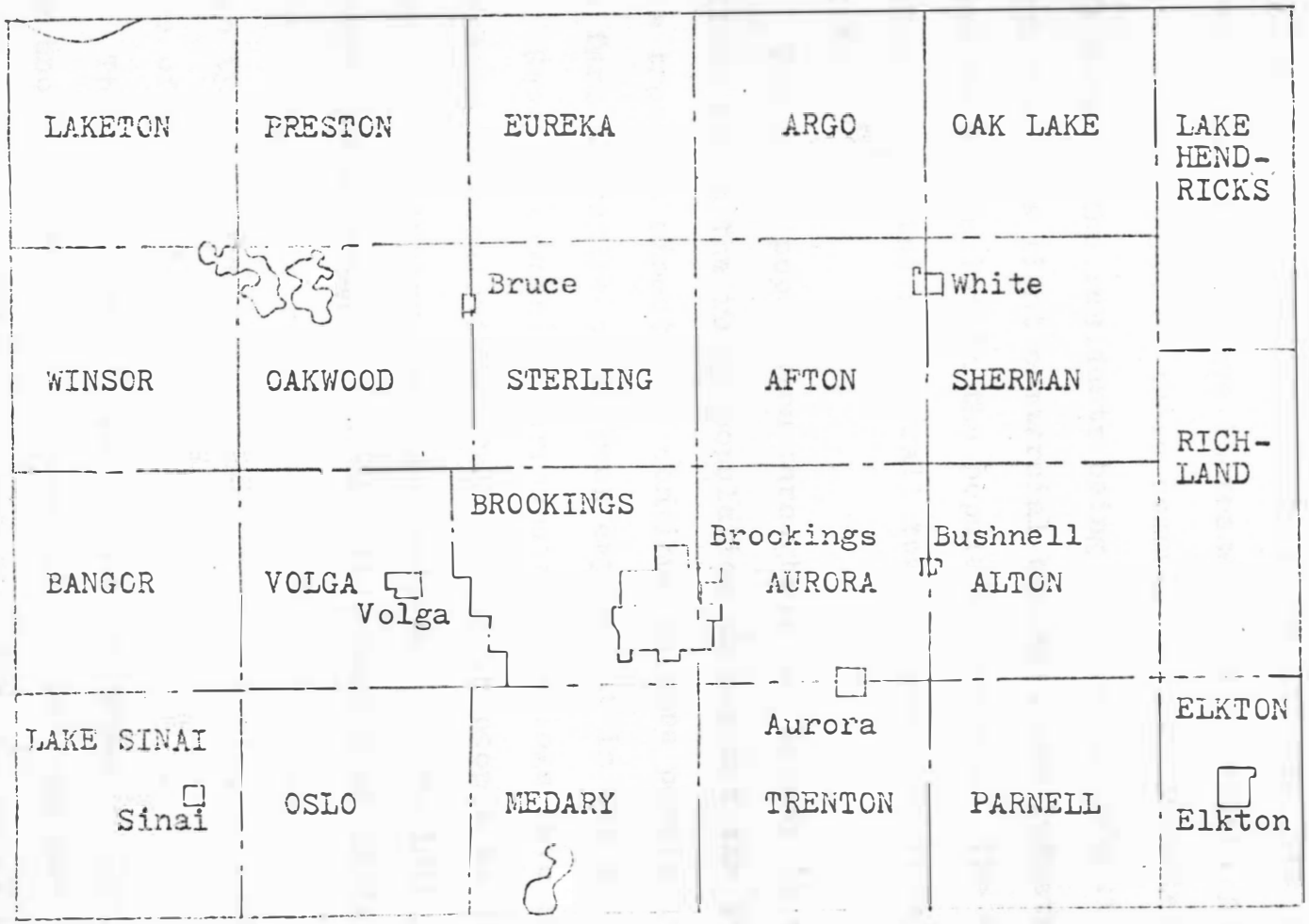

Figure 1: Map of Brookings County, South Dakota, Showing the Townships and Towns.

The small towns farthest away from Brookings: Elkton, White, Bruce, Sinai and Bushnell show a declining population, as do most small towns in South Dakota. The towns of Volga and Aurora have increased in population, particularly Volga. Both of these communities are commuter towns with many of the residents being employed in Brookings. Volga has some light commercial business and industry which help to maintain the population growth. The total population of the seven small towns appears to remain steady.

The rural population throughout the County is on a decline as is the rural population throughout the State. This trend is expected to continue as more people leave the farm to retire or to seek employment in the cities.

Several townships surrounding Brookings have shown an increase in population. This is due to people moving to rural areas, buying small acreages and the building of several rural trailer courts. This method of living has become popular in recent years and is expected to continue. This type of development adds to the population and tax base of the rural area involved.

The population of the various segments of the County are shown in Table 2. A population study was made for the County and the estimated population for the years 1980, 1990, and 2000 is shown in Table 3. The detailed population

Table 2: Population of Towns and Townships of Brookings County, South Dakota, Number of Units and Population Density, 1970(4).

Town or Township	1970 Population	No. of Units	Population Per Unit
Rural			
Afton	235	69	3.41
Alton	258	70	3.69
Argo	211	62	3.40
Aurora	290	82	3.54
Bangor	234	70	3.34
Brookings	398	107	3.72
Elkton	148	42	3.52
Eureka	215	64	3.36
Lake Hendricks	185	60	3.08
Laketon	203	61	3.33
Lake Sinai	226	65	3.48
Medary	508	153	3.32
Oak Lake	233	66	3.53
Oakwood	226	65	3.48
Oslo	260	80	3.25
Parnell	227	58	3.91
Preston	239	73	3.27
Richland	203	58	3.50
Sherman	178	44	4.05
Sterling	304	92	3.30
Trenton	273	73	3.74
Volga	324	96	3.38
Winsor	256	68	3.76
Total Rural	5834	1678	3.48
Towns			
Brookings	13717	3673	3.73
Aurora	237	79	3.00
Bushnell	65	23	2.83
Elkton	541	200	2.71
White	418	164	2.55
Bruce	217	79	2.75
Sinai	147	60	2.45
Volga	982	320	3.07
Total Towns	16324	4598	3.55
Total County	22158	6276	3.53

Table 3; Estimated Population for 1980, 1990 and 2000 for Brookings County and its Subdivisions(4) (Appendix A).

Town or Township	1970 Population	Estimated Population 1980	1990	2000
Rural				
Afton	235	187	145	109
Alton	258	207	160	121
Argo	211	169	131	99
Aurora	290	233	180	136
Bangor	234	188	146	110
Brookings	398	411	424	436
Elkton	148	119	92	69
Eureka	215	173	134	101
Lake Hendricks	185	149	115	87
Laketon	203	163	126	95
Lake Sinai	226	181	140	106
Medary	508	524	541	554
Oak Lake	233	187	145	109
Oakwood	226	181	140	106
Oslo	260	209	162	122
Parnell	227	182	141	106
Preston	239	192	149	112
Richland	203	163	126	95
Sherman	178	143	111	84
Sterling	304	244	189	143
Trenton	273	219	170	128
Volga	324	260	201	152
Winsor	256	206	160	121
Total Rural	5834	4890	4028	3301
Towns				
Brookings	13717	17235	20984	25293
Aurora	237	239	241	245
Bushnell	65	46	30	17
Elkton	541	448	364	291
White	418	414	409	403
Bruce	217	162	115	74
Sinai	147	127	108	91
Volga	982	1176	1372	1574
Total Towns	16324	19847	23623	27988
Total County	22158	24737	27651	31289

study is attached as Appendix A. These estimates of future populations were based on several different methods and represent forecasts that rely on past experience. Unforeseen events may occur which could result in actual future populations drastically different from the predicted values.

Counties that have urban centers within their boundries, such as Brookings County, are showing growth. Counties adjacent to Brookings County, none of which have a large urban population, all show a population decline. Statewide, the rural population is declining because the number of farms is decreasing about two percent per year(5).

SOLID WASTE

General Descriptions and Definitions

The term solid waste should be defined prior to any discussion, as should many related terms. The uses of many of these terms have been interchanged and misused in the past and some confusion has resulted. From the dictionary, the word "garbage" means "trash", which is defined as "refuse", which is described as "rubbish", which again means "trash" or "debris"(6). There are more than 30 synonyms for "garbage" in Roget's Thesaurus(6). It is common practice for a solid waste collection agency to use one of the many terms to mean all material collected and disposed of. For the purpose of this study the following terms and definitions will be used.

The word "waste" will refer to useless, unused, unwanted or discarded materials in any form, solid, liquid, or gas. The gasses are principally industrial fumes and smoke; the liquid being mainly sewage and industrial waste waters; and the solids primarily refuse. Therefore, the term refuse and solid waste will be used interchangeably(6).

The term "refuse" refers to solid waste, with many varying components and quantities. Refuse can be classified according to point of origin and thus it is possible to have domestic, industrial, commercial, institutional, street, and demolition refuse. Refuse can also be

classified as organic or inorganic, combustible or non-cumbustible, or putrescible or nonputrescible. The most useful classification is probably the one based on the kinds of material: garbage, rubbish, ashes, street refuse, dead animals, abandoned automobiles, industrial waste, demolition wastes, construction wastes, sewage solids, and special wastes. The composition of many of these materials may be found in Table 4.

Garbage is the solid or semi-solid putrescible animal or vegetable waste resulting from the handling, preparing, cooking, storing, serving and consuming of food. The term does not include waste from food processing plants, canneries, slaughterhouses or similiar industrial plants. Garbage originates primarily in home kitchens, stores, restaurants and other places where food is stored or prepared. Garbage decomposes very rapidly, particularly in warm weather and may produce odors. It is also a food for rats and other vermin and a breeding place for flies. The term swill, slops and offal are frequently used to define garbage but are not synonymous. Swill and slops denote semi-liquid garbage and free liquids. Offal is used only to describe discarded parts of slaughtered animals.

Rubbish consists of a variety of both combustible and non-combustible solid wastes from homes, stores and institutions. Trash and rubbish are generally considered to mean

Table 4: Refuse Materials by Type, Composition and Sources(7).

Kind	Composition	Source
Garbage	Waste from preparation, cooking and serving of food; Market refuse, Waste from the handling, storage, and sale of produce.	Homes, hotels, institutions, stores, markets
Rubbish	Combustible: Paper cartons, boxes, barrels, wood and excelsior, tree branches, yard trimmings, wood furniture, bedding.	
	Noncombustible: Metals, tin cans, metal furniture, dirt, glass, crockery, other minerals.	
Ashes	Residue from fires used for cooking and for heating buildings.	
Street Refuse	Street sweepings, dirt, leaves, catch basin dirt, contents of litter receptacles	Street, alleys, sidewalks, vacant lots, parks, etc.
Dead Animals	Small animals: cats, dogs, etc. Large animals: horses, cows, etc.	
Industrial Refuse	Solid waste resulting from industrial processes and manufacturing operations, such as food processing wastes, boiler house cinders, lumber scraps and shavings, metal scraps and shavings, and other waste from industry.	Factories, power plants, processing plants.

the same type of material. Combustible rubbish consists mainly of paper, rags, cartons, boxes, wood, excelsior, bedding, rubber, plastics, tree branches, leather, lawn clippings and like material. Combustible rubbish is not highly putrescible and therefore may be stored for relatively long periods. It has a high heat value and burns freely without added fuel. Non-combustible rubbish is material that is unburnable at ordinary temperatures, that is from 1300 to 2000 degrees Fahrenheit, and consists of metal, crockery, glass, dirt, ashes and similiar material. It is very slow to disintegrate and may become objectionable from an aesthetic view. Some of these materials have salvage value. Street refuse is the material picked from streets by manual or mechanical sweepers and is mostly dirt, leaves and paper.

Dead animals are particularly offensive from both a sanitary and aesthetic point of view, and must be disposed of at once. Any delay presents a serious health hazard.

Industrial refuse is the solid material from factories, processing and other manufacturing plants. The collection of such waste is generally the obligation of the owner(6).

Demolition refuse is solid material from razed buildings and other structures. It is very similiar to construction refuse, however, construction refuse is

usually a very small quantity compared to demolition waste. Both consist mainly of wood, concrete, plaster, brick and other construction material, all of which is very bulky.

Composition of Solid Waste

The composition of solid waste is very complex and influenced by population density, socio-economic levels, seasons, local resources, local industry, living habits and other factors. Many of these factors change with time. The composition of solid waste as reported by the United States Department of Health, Education and Welfare is shown in Table 5.

Table 5: Composition of Solid Waste(8).

Classification	Percent, by Weight
Putrescibles	25
Small Combustibles	53
Small Non-combustibles	18
Other, Bulky Waste	4

The approximate composition of solid waste from residential collections is shown in Table 6. This table gives a more detailed analysis. It can be seen that 50 percent of the total consists of paper products. Most of the reported values are for municipal or residential

collection and do not involve areas that are basically rural. However, it is expected that the composition of the solid waste collected from rural locations would be similiar. Rural collection systems are not expected to dispose of agriculture waste products from farms.

Table 6: Composition of Residential Solid Wastes(9).

Component	Percent, by Weight
Food Waste	15
Paper Products	50
Plastics, Rubber, Leather	3
Rags	2
Metals	8
Glass and Ceramics	8
Wood	2
Garden Waste	5
Rocks, Dirt, Misc.	7
Total	100

Table 7: Weight of Refuse Under Certain Conditions(9).

Condition of Refuse	Weight, Pounds Per Cubic Yard
Loose refuse at curb	125-240
Normal compacted refuse in a sanitary landfill	750-850
Well compacted refuse in a sanitary landfill	1000-1250
Refuse in a compactor truck	300-600
Shredded refuse, uncompacted	600
Shredded refuse, compacted	1600
Refuse compacted and baled	1600-3200
Apartment house compactor	700

From the time it is collected until its final disposition, solid waste must be handled in its original loose condition, compacted in trucks and in the landfill. The density is different for each condition. The various weights and densities are shown in Table 7.

Solid Waste Legislation and Regulation

The 1972 Legislature of the State of South Dakota passed the South Dakota Solid Waste Act of 1972 and subsequently statewide standards for collection and disposal of solid wastes were implemented(10). In addition, the State issued Air Pollution Control Regulations for South Dakota in January, 1972, which also imposed certain restrictions upon solid waste disposal(11). This Air Pollution Control Regulation prohibited private and public burning of trash, refuse and garbage effective July 10, 1973. However, variances have been issued to allow time for compliance with these regulations.

The South Dakota Department of Environmental Protection has developed regulations establishing a timetable for the counties of South Dakota to submit a solid waste management plan to them for approval(12). This timetable is as follows: municipalities with population of ten thousand or more, by July 1, 1974; those having a population of 4000 to 10,000, by July 1, 1975; and those with a population less than 4000, by July 1, 1976.

Regulations also require the implementation of an approved solid waste management system by counties having a population of 10,000 or more by July 1, 1975; those having a population of five to ten thousand by July 1, 1976; and those having a population of less than five thousand by July 1, 1977(12). As of March, 1974, none of the counties in the First Planning and Development District had complied.

Solid Waste Management

Achievement of a satisfactory collection and disposal system for the management of solid wastes requires that sufficient consideration be given to the following items: planning, storage, collection, disposal, finance and public awareness and cooperation.

Solid waste collection and disposal are similiar to other public services and should receive the same careful planning and consideration if existing inadequacies are to be corrected. However, to date, the emphasis has been on streets, communications, water supplies, wastewater treatment facilities, electric utilities and other services and solid waste disposal has not received adequate attention. Because of the rural nature of South Dakota the State has recommended that planning for solid waste management systems not be confined to one single community(1).

The first factor that must be considered is the source of solid wastes. The Department of Environmental Protection advocates the adoption of local ordinances which establish control over solid wastes at the source, or storage site(1). On-site storage must be regulated by the community to prevent unsightliness and attraction of flies and rats. The regulation of on-site storage should also cover the practice of backyard burning which can cause smoke and odor nuisance and increased fire hazard, in addition to unsightly litter scattered by the wind prior to burning. It is usually the responsibility of the home-owner or the business proprietor to supply proper and adequate containers and to maintain them in good condition. The local governments usually assume the responsibility for defining "proper storage" and for enforcing the standards. If individual pickup is to be provided, the size of on-site containers should not exceed 20 to 32 gallons in capacity for rubbish and should not weigh more than 70 pounds when filled(9). Proper lids and stands should be provided to prevent problems of odors and flies.

Routine, scheduled collection of solid waste is a basic necessity in maintaining a clean community, free from an accumulation of solid waste. It has been well established that all refuse should be removed from each residence at least twice a week(1), to minimize the health hazard.

Collection schedules vary from one community to another depending on physical circumstances, attitudes of citizens, financial factors and environmental standards. There are four ways solid waste collection is implemented currently in South Dakota. These are: (a) municipal collection, (b) contract collection, (c) private collection, and (d) no collection. Municipal collection is carried out by city employees and city-owned equipment. Under contract system, a private contractor collects the waste under an agreement with the city. Private collection involves an arrangement between the contractor and each citizen for collection. Under the "no collection" approach, each householder is responsible for hauling his own refuse to the disposal site. The first two methods are recognized as being the most efficient and reliable and the easiest to regulate(1). The last method is considered very inadequate and usually leads to refuse problems in the community due to the failure of some individuals in properly transporting and disposing of the solid waste.

The third factor that must be considered in good solid waste management is the disposal of the refuse. In the past, the most common method of disposal was the open dump, however, the Solid Waste Act renders this method unacceptable in the State. An open dump provides an ideal environment for rats and flies, contributes to air

pollution from burning, causes surface and ground water contamination, causes land degradation and usually creates a general nuisance. The continued use of the open dump is attributed to the low direct costs with no thought given to the indirect costs of poor sanitation and other hazards to health. Also, factors such as fire hazard, land depreciation adjacent to the dump, and pollution of ground water were given little consideration. The inherent characteristics of an open dump are not compatible with current living and health standards and are not in keeping with existing technology.

There are several alternative methods of disposal; incineration, garbage reduction, composting, pyrolization, and use of sanitary landfill. All but the sanitary landfill require a large volume of waste for economic operation or special equipment and, in most cases, a separation of the various components of the refuse. From a practical standpoint, the sanitary landfill is the only method that can be successfully adapted to South Dakota. In brief, the sanitary landfill is an engineered method for disposing of solid waste on land by spreading it in thin layers, compacting the waste to the smallest practical volume, and covering with soil each day in a manner that protects the environment(9).

For a predominently rural area such as South Dakota, one approach which may be applicable in implementing an effective solution to the solid waste problem is the establishment of area or regional solid waste management programs(1). Under such an arrangement several communities would enter into a joint agreement for the collection, transportation and disposal of all waste material. Disposal would be confined to a central sanitary landfill rather than use of several open dumps such as now exist. While the proposal is mainly concerned with smaller towns there is no reason it could not be broadened to include totally rural areas.

Regional systems would alleviate the problem of inadequate financial support attributed mainly to the lack of large enough population concentrations to finance independent community systems at reasonable unit costs. In adopting the regional system small communities would unite together to share equipment and operational costs. Legislation authorizes county units of government to enter the area of solid waste management according to the South Dakota Code, SDCL 1967, 7-33-1 (1). This provides the legal mechanism to extend service to unincorporated communities and rural families in areas where population is sufficient to warrant rural service.

Table 8: Quantities of Solid Waste from Previous Studies.

Location	Population	Year	Tons/ Year	Pounds/ Capita/ Day	Notes	Reference
State of S. Dak.	666,257	1973	523,000	4.3	Generated	(1)
Des Moines, Iowa	288,000	1968	562,000	(10.69)	Total solid waste	(13)
	418,000	1990	783,000	(10.26)	Total solid waste	
		1968	141,000	(2.68)	Residential only	
Englewood, Colo.	79,038	1960		2.0	Residential	(14)
	146,500	1970		2.0	Residential	
	206,500	1980		2.0	Residential	
New Orleans, La.	868,480	1969		5.69	All solid waste	(15)
State of Calif.	19.5Mil.	1967		6.5	Municipal	(16)
Brown County, Wisconsin	170,610	1970		3.9-4.9		(8)
	204,630	1975-1985		4.8-6.0		
	270,050	1985-2000		7.0-7.9		
Fresno, Calif.	396,000	1967		(5.98)	Municipal	(17)
Omaha, Nebr.	299,000	1957		(3.75)	Total	(6)
Seattle, Wash.	575,000	1957		(3.75)	Total	(6)

Table 8: Quantities of Solid Waste from Previous Studies, Continued.

Location	Population	Year	Tons/ Year	Pounds/ Capita/ Day	Notes	Reference
Humphrey Co., Tennessee	12,930	1970		3.5	Generated-County	(18)
South Dakota First District Planning Area *	108,513	1974 1990		4.26 8.9	Generated Generated	(12)
Brookings County South Dakota	5,860	1974		2.0	Rural Area Only	(19)
National Average		1968 1968		5.3 7.0	Collected Generated	(16)

* Brookings County is in the South Dakota First District Planning Area.

As with any civic program, providing a solid waste collection and disposal service must have the support of the public to succeed. The citizens must be informed of the advantages of such a program as well as the cost. The local government should be responsible for disseminating facts and objectives of the proposed system.

Quantities of Solid Waste

Quantities of solid waste as determined from published reports are shown in Table 8. Most of the data are from studies in metropolitan areas where most of the investigations were conducted. The national averages were 5.72 pounds of solid waste per capita per day for urban sources and 3.93 pounds per capita per day for rural areas(16). These values are about the same as those from other studies made for rural areas. Table 9 includes a breakdown of the National averages according to source for urban, rural and average per capita solid waste production.

Table 9: National Average per Capita Solid Waste Collection, 1968(9)(16).

Source	Pounds per Capita per Day		
	Urban	Rural	National
Household	3.19	2.98	3.11
Commercial	1.16	0.45	1.04
Industrial	0.65	0.37	0.59
Demolition	0.23	0.02	0.18
Streets	0.11	0.03	0.09
Miscellaneous	0.38	0.08	0.31
Total	5.72	3.93	5.32

The City of Brookings made a rough estimate of the quantities of solid waste collected in the residential area in August, 1970.[1] These quantities do not include wastes from commercial or industrial areas. The amount of solid wastes collected and the weight are shown in Table 10.

Table 10: Sample Weights of Solid Waste Loads in Brookings, South Dakota, August, 1970.

Day	Total Weight Collected Pounds per Load		
	Plastic Bag	Cans	
Tuesday AM	8,070	9,450	
Friday AM	5,500	7,700	
Wednesday PM	9,300	11,050	
Friday PM	4,000	6,250	
Total Weighed	26,870	34,450	
Average, Pounds per Load			7,665

Eight loads were weighed and considered typical. Since there were two collections per week, the total weight of solid wastes collected per week was found by multiplying the values shown by two. At that time the City was collecting a total of 16 loads per week from sixteen routes. Since the population of Brookings includes the students at South Dakota State University, the amount of solid waste collected by the University should be included in the total.

1. Private communication from Lloyd Darnell, City Engineer, Brookings, South Dakota.

The amount of solid waste collected by the University was obtained from information gathered in February, 1974.[2] These data are presented in Table 11.

Table 11: Sample Weights of Loads of Solid Waste Collected at South Dakota State University, February, 1974.

Day	Total Weight Collected Pounds per Day
February 25	8,000
February 26	6,630
February 27	7,400
February 28	6,010
March 1	6,710
Total weight per week	34,750

The total of these two sources provide an estimate of the total solid waste collected in the City of Brookings, residential area and the University. This data is listed in Table 12.

Table 12: Estimated Total Weight of Solid Waste Collected in Residential Area and University, Brookings.

Source	Weight Collected Pounds per Week
City of Brookings, Residential	122,640
South Dakota State University	34,750
Total	157,390

2. Private communication from Charles Olson, Grounds Superintendent, South Dakota State University.

The residential solid waste collected is estimated at 1.63 pounds per capita per day. This value is below the national average for urban areas, but compares with rural quantities. As shown in Table 8, the study made in Humphreys County, Tennessee in 1972 indicates 2.5 pounds per capita per day collected and 3.5 pounds per capita per day generated(18). This is a rural area that includes several small towns and should be comparable to Brookings County. The study of the First Planning and Development District used a two pounds per capita per day for a generation rate for rural households(19). As shown in Table 8, this quantity is substantiated by a study made by the South Dakota Department of Health on a statewide basis(20).

SOLID WASTE COLLECTION AND DISPOSAL FOR BROOKINGS COUNTY

General

The Department of Environmental Protection regulations require Counties over 10,000 population to submit a plan for solid waste management and to be in compliance with the appropriate regulations by July, 1975(1). Brookings County is included in this category; however, the plans submitted so far are for cities and towns and do not include the rural areas. A problem would arise, however, when open dumps now serving the small towns are closed and the rural residents of these areas no longer have a place to dispose of their solid waste. The only other area where these people can legally dispose of refuse is on their own land. Thus, many more open dumps would be created, each small in size. The regulations provide that no more than three persons or family units can use any one private site. The private disposal of refuse while relatively inexpensive, is not desirable from a health standpoint, or from an aesthetic view. In the past, it was common for each rural resident to accumulate solid waste somewhere on his property and then haul it to a dump periodically. This practice led to large accumulations of waste on many rural farmsites. This practice should be discontinued. In order to accomplish this a solid waste management plan for a rural solid waste collection system should be devised and implemented.

Collection of Waste in the Small Towns

At this time it appears that the seven small towns in Brookings County will all adopt the Solid Waste Plan developed by the First Planning and Development District(19). This plan includes several alternatives. Most or all of the towns will apparently use the present Brookings City Landfill for refuse disposal. The solid wastes will be collected by a private contractor. The City of Brookings has agreed to let the entire County use its landfill. It is estimated that the present landfill has a capacity for disposal of refuse from the City of Brookings until the year of 2000. The use of this landfill by the entire County is expected to shorten this life somewhat. Use of the City of Brookings landfill would permit the small towns to close their open dumps and cover these areas to conform with State regulations. However, the closing of these dumps will create a problem for rural residents, since this will eliminate the convenient local disposal sites. Figure 2 shows the present open dump locations. It can be readily seen that these sites are spread throughout the County, providing ready access to most residents because of the relative short haul distance. Table 13 includes the locations and estimated quantities of refuse presently existing in each of the dumps shown in Figure 2. The Volga dump is no longer used.

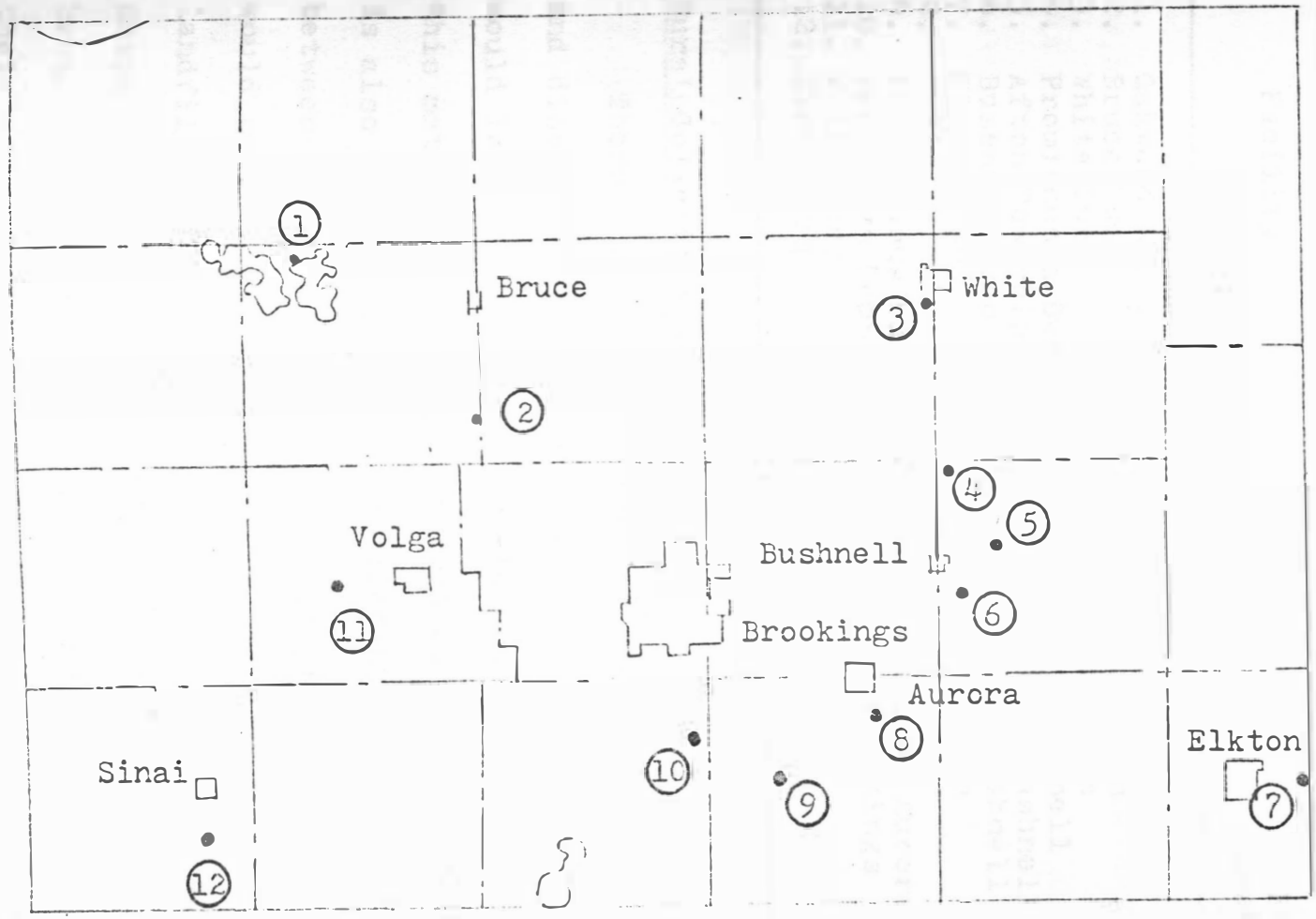

Figure 2: Location of Present Brookings County Disposal Sites.

Table 13: Disposal Facilities Presently Located In Brookings County, Location and Estimated Quantities.

	Facility	Location	Estimated Quantity, C.Y.
1.	Oakwood State Park	SE of Tourist Area	260
2.	Bruce Dump	2½ Mi. S of Town	5555
3.	White Dump	½ Mi. SE of Town	6667
4.	Promiscuous Dump	3 Mi. N of Bushnell	100
5.	Afton Township Dump	2 Mi. E, 1½ N Bushnell	890
6.	Bushnell Dump	1 Mi. E, ½ S Bushnell	1295
7.	Elkton Dump	1½ Mi. e of town	3340
8.	Aurora Dump	SE edge of Town	555
9.	Promiscuous Dump	2 Mi. S, 2 W of Aurora	185
10.	Brookings Dump	3 Mi. S of Brookings	Unknown
11.	Volga Dump	1 Mi. W of Town	5555
12.	Sinai Dump	1 Mi. W of Town	1850

Rural Collection Systems

There are several alternative methods of collecting and disposing of solid wastes in rural areas. One method would involve periodic house-to-house collection. While this method is probably the best collection procedure, it is also the most costly, considering the miles traveled between stops and the time involved. Another approach would be to rely on the owner to transport his waste to a landfill site for disposal. With the closing of all open dumps in the County, this alternative becomes undesirable because many of the rural residents would have to haul their waste long distances. This inconvenience would deter many from adequately disposing of the refuse. A

third alternative would consist of a combination of the first two methods. This approach would require the rural residents to haul their refuse to a nearby collection point. A collection agency would then haul the solid waste to a central sanitary landfill on a weekly or twice-weekly basis depending on the quantity and season. The collection agency could be either a local governmental agency or a private contractor. The merits of both should be investigated.

The neighborhood sites should be located to provide easy access for the utmost convenience to rural residents. The sites should be located adjacent to the more heavily traveled, hard-surfaced, all-weather roads wherever possible. The type of refuse would be limited to ordinary household solid waste and would not include agriculture or animal waste which would be disposed of on the land as is now the practice.

Brookings County Solid Waste Quantities

At the present time, the only routine solid waste collection programs in the County are in the City of Brookings and in Volga. Thus, the quantities of refuse generated in Brookings County will have to be estimated using data from the literature. Some of the values found in previous studies are shown in Table 8. It is believed that the values promulgated by the State Health Department

and the First Planning and Development District will provide reasonable estimates of solid waste production in Brookings County. These values are: 4.3 pounds per capita per day for cities and towns; and 2.0 pounds per capita per day for rural areas(1)(12)(20). These values are higher than those reported for the City of Brookings, and therefore may be somewhat conservative; however, they will be used for this study. An increase of two percent per year in the quantity generated and collected for municipal waste and 2.5 percent for rural areas is anticipated on the basis of other investigations(16)(21).

A tabulation of the estimated quantities of solid waste for Brookings County based on the unit values mentioned above and the estimates of future populations shown in Table 3, for the years 1970, 1980, 1990 and 2000 is presented in Table 14, and shown in detail in Appendix B.

Temporary Residents

There are three areas in Brookings County that experience an increase in population during the summer. These areas are adjacent to Lake Campbell, Lake Poinsett and Oakwood Lakes. These summer residents create a solid waste disposal problem that should be considered in the establishment of solid waste collection systems. The estimated population of these areas can be found by counting the number of summer residences and applying an

Table 14: Summary of Estimated Solid Waste Quantities for Brookings County, 1970, 1980, 1990, and 2000.

Area	Pounds Per Week	Volume, Cubic Yards Per Week Loose	Compacted
1970			
Total Rural	81,676	466	182
Total Towns	491,351	2,808	1,092
Total County	573,027	3,274	1,274
1980			
Total Rural	85,631	489	190
Total Towns	716,870	4,096	1,593
Total County	802,501	4,885	1,783
1990			
Total Rural	87,969	503	196
Total Towns	1,023,596	5,849	2,274
Total County	1,111,565	6,452	2,470
2000			
Total Rural	90,118	515	200
Total Towns	1,455,755	8,319	3,235
Total County	1,545,873	8,834	3,435

estimated per capita production value. A recently published County map shows approximately 191 temporary cottages. Using a value of 3.5 persons per unit, the estimated temporary population would be 669. The total number of housing units in the County in 1970 was 6889 with the number of permanent residences listed as 6724(4). The difference is 165, which if assumed to be temporary units, would represent a temporary population of about 498, using the average population of Brookings County of 3.02 persons per unit(4). These people could probably be

considered vacationers, which would mean that the unit would be occupied more frequently on weekends and mostly from May to September. The estimated quantity of solid waste at two pounds per capita per day for these temporary residents, would be 1338 pounds per day or about 7.7 cubic yards per day, loose. In the interest of public health and safety some arrangement should be made to collect this refuse. The estimated quantities for the temporary residents are shown in Table 15.

Table 15: Temporary Residents and Solid Waste Quantities, 1970.

Area	Number of Summer Units	Estimated Population (3.5 Per Unit)	Solid Waste Generated Pounds Per Week	Cubic Yards Per Week
Lake Poinsett	82	287	4018	23.0
Oakwood Lakes	37	130	1820	10.4
Lake Campbell	72	252	3528	20.2
Total	191	669	9366	53.6

Since the amount of land available at the three lakes is limited, it is not expected that a large growth would take place; however, certainly some growth would occur. It is estimated that a growth of ten percent per decade would be reasonable. Using this population and solid waste quantities mentioned above, the future amounts of refuse generated would be as shown in Table 16.

Table 16: Future Quantities of Solid Waste from Temporary Residents in Brookings County.

Area	Population	Pounds of Solid Waste Per Week	Loose Volume Cubic Yards Per Week
1980			
Lake Poinsett	316	5530	31.6
Oakwood Lakes	143	2502	14.3
Lake Campbell	277	4848	27.7
Total	736	12880	73.6
1990			
Lake Poinsett	347	7578	43.3
Oakwood Lakes	157	3429	19.6
Lake Campbell	305	6661	38.1
Total	809	17668	101.0
2000			
Lake Poinsett	382	10429	59.6
Oakwood Lakes	173	4723	27.0
Lake Campbell	335	9146	52.3
Total	890	24298	138.9

The pollution and littering of recreation areas has been a problem and a solution would be beneficial to all, including the adjacent property owners. In addition to the summer residents on these three lakes, there are picnic areas, camp grounds and other public areas that generate refuse. The same collection used for the summer residents could be utilized to service the public recreation areas.

Adjacent Towns

The study by the First Model Development District indicates that there are other towns in the adjoining

counties that will have solid waste disposal problems(12). While these counties have a lower population and are not required to have a solid waste disposal plan until 1975, it would be advisable to consider them in any rural or county-wide disposal system devised for Brookings County. There are no landfills in the adjoining counties. The adjacent towns in these counties are Arlington, Estelline, Toronto, Astoria and Ward. All of these communities are within a few miles of the Brookings County line. The population of these towns and the estimated quantities of solid waste for each are shown in Table 17.

Table 17: Population and Estimated Solid Waste Quantities of Towns Adjacent to Brookings County.

Town	Population			Pounds per Week (1970)	Cubic Yards Per Week Loose
	1950	1960	1970		
Arlington	1096	996	954	4102	23.4
Astoria	206	176	153	658	3.8
Estelline	760	722	624	2683	15.3
Toronto	322	268	216	929	5.3
Ward	96	74	57	245	1.4
Total	2480	2236	2004	8592	49.2

COLLECTION EQUIPMENT

The neighborhood collection sites should be provided with containers in which the rural residents can deposit their refuse for collection. Present littering laws prohibit the hauling of refuse in open trucks, even though this type of truck may be available from the local government agencies. Thus, the collection of the refuse would utilize closed trucks with a variety of equipment available. The packer box or body, which reduces the volume of the refuse would be required. This type of equipment would not only reduce the volume, but is enclosed to prevent the spilling and spreading of the refuse after collection. The three main types of packer bodies are: the front-loading; the side-loading; and the rear-loading type. There are various modifications of each of these types as well as several other packers available.

The rear-loader packer body is probably the most common and widely used. The rear-loader normally requires a three-man crew; a driver and two loaders. This type is normally used in door-to-door collection where refuse is stored in trash cans. Usually one man takes each side of the alley or street and manually dumps the refuse in the rear hopper. This system requires a great deal of manual labor and is a dangerous occupation to the loader. A variation of this method involves the use of plastic bags

in place of garbage cans. This reduces the weight a person must lift and eliminates the return trip with the empty can, thus reducing the collection time. Larger containers, which are dumped mechanically, are also available for rear loading packers, but these present a problem in alignment for loading. A hard surface is required for the placement of these containers and a two-man crew is required. Several companies make this type of equipment.

The front-loading packer body is becoming more popular and is being used for some rural systems(18). This type of truck is driven directly into the container, which is lifted over the cab by a hydraulic system, and dumped into the packer. Only a driver is required and he does not have to leave the cab. There are disadvantages, however, one of which is the extra heavy load placed on the front of the truck, requiring a special truck. Also, a hard-surfaced area is required to place the containers and to park the truck so that proper alignment can be obtained in all types of weather.

The side-loading truck is available for use on small cans, manually dumped or for larger containers, mechanically dumped. This container system requires two men: a driver and a loader to connect the containers; although a new type of truck has been developed requiring only one man. This side-loading system has the advantage of requiring less

space because the truck is driven along side the container. This unit also requires less precision in loading and is easier to maneuver than the other systems.

Another system worth mentioning is the roll-off container system, where a large container is loaded on the truck and hauled to a landfill and emptied. A spare container must be provided at the collection site while the other is being emptied. This system utilizes fewer but much larger containers. This might result in fewer collection sites and longer haul distances for the users. This inconvenience may offset any advantage of the roll-off system.

Several modifications of the front- and side- loading systems are available such as bag retrievers and barrel snatchers(21). These are not widely accepted to date, but may be adopted in the future.

Packer bodies for the trucks vary from about 14 cubic yards capacity to thirty cubic yards. The volume is for compacted refuse having a density of 300 to 600 pounds per cubic yard, with a typical value of 450 pounds per cubic yard. The capacity required in each case is determined by a study of total volume to be collected, number and length of routes, and the cost of the units, both initial and operating.

The containers used with the front-loading, side-loading and rear-loading truck types are very similiar, the only difference being the shape and the method of lifting to empty. The size of the containers range from one cubic yard to six cubic yards. The density of loose refuse is about 175 pounds per cubic yard, so the weight of refuse in each container would range from approximately 175 to 1050 pounds. Table 18 includes the various sizes of refuse containers, the various sizes of compactor trucks and the number of containers each can accomodate. The values in Table 18 are based on 175 pounds per cubic yard loose weight in the container and 450 pounds per cubic yard of compacted weight in the packer truck. The size of the containers required depends largely upon the density of population and availability of collection sites. Rural residents ideally should not have to drive farther than four to five miles to a collection site(7).

Table 18: Container and Truck Sizes Available.

Container Size Cubic Yards	Truck Size Cubic Yards	Number of Containers Per Truck
3	13	11
	16	13
	20	17
	24	20
	28	24
4	13	8
	16	10
	20	13
	24	15
	28	18
	30	19
6	16	6
	20	8
	24	10
	28	12
	30	13

RURAL COLLECTION AND DISPOSAL

Proposed Method of Solid Waste Collection from Rural Areas of Brookings County

As previously mentioned, the collection of solid waste from rural areas could be accomplished in several ways. From previous discussion of the various methods, it would appear that the best method of rural collection involves the use of local or community collection sites. Therefore, this method of collection will be used to design a system for the rural area of Brookings County. The necessary equipment and containers should be standard manufactured products and could be operated either by County employees or by a private contractor.

The number and location of the collection sites is dependent upon the size of available containers and the number of containers that can be provided at each site. Containers vary in size from one to six cubic yards(12). Three- and four-cubic yard containers can be used with the side-loader and the three-, four- and six-cubic yard containers with the front-loader. If the front loader is used, a larger hard-surfaced area would be required to maneuver the truck; however, the fewer sites needed if the six-yard containers were used could offset the requirement of additional area. Because the cost of the sites and site

preparation is a major part of the collection system cost, it is desirable to hold the number of sites to a minimum. The smaller-size containers, one-yard and two-yard capacity, are designed to service individual users rather than for multiple users. The larger containers, three- to six-yard capacity, are much better suited to multiple user applications. Table 19 contains a summary of the estimated number of containers required for the rural area of Brookings County for 1970, 1980, 1990 and 2000. Estimates from which this summary was obtained may be found in Appendix D.

Table 19: Summary of Number of Containers Required for Rural Brookings County by Year, 1970 to 2000.

Container Size Cubic Yards	Estimated Number of Containers 1970	1980	1990	2000
3	156	164	167	172
4	116	121	126	129
6	78	81	85	87

The number of containers required increases from 156 to 172 for three-yard containers, 116 to 129 for four-yard containers, and 78 to 87 for six-yard containers from the year 1970 to the year 2000. The total number of containers required is not expected to increase substantially over the next thirty years because, although the population of the rural areas is projected to decline, the quantity of solid

waste generated per capita is expected to increase with the net result of only a slight increase in total volume.

The solid waste from temporary residents and public areas should be included in a rural collection system. The number of containers required for these areas is shown in Table 20. The detailed estimate of the number from each area is included in Appendix D.

Table 20: Summary of Number of Containers Required for Temporary Residents of Brookings County by Year, 1970 to 2000.

Container Size Cubic Yards	Estimated Number of Containers 1970	1980	1990	2000
3	18	25	34	47
4	14	19	26	35
6	9	13	17	23

The location of the collection sites, as previously mentioned, would be adjacent to hard-surfaced roads where possible and near centers of population. Figure 3 shows the location of hard-surfaced highways and good graveled roads. The sites would be located so that rural residents would not have to drive over four miles to a collection site. The locations of the rural collection sites designed for four-yard containers are shown in Figure 4 and the detailed locations within each township shown in Appendix C. The number of containers required for each township is

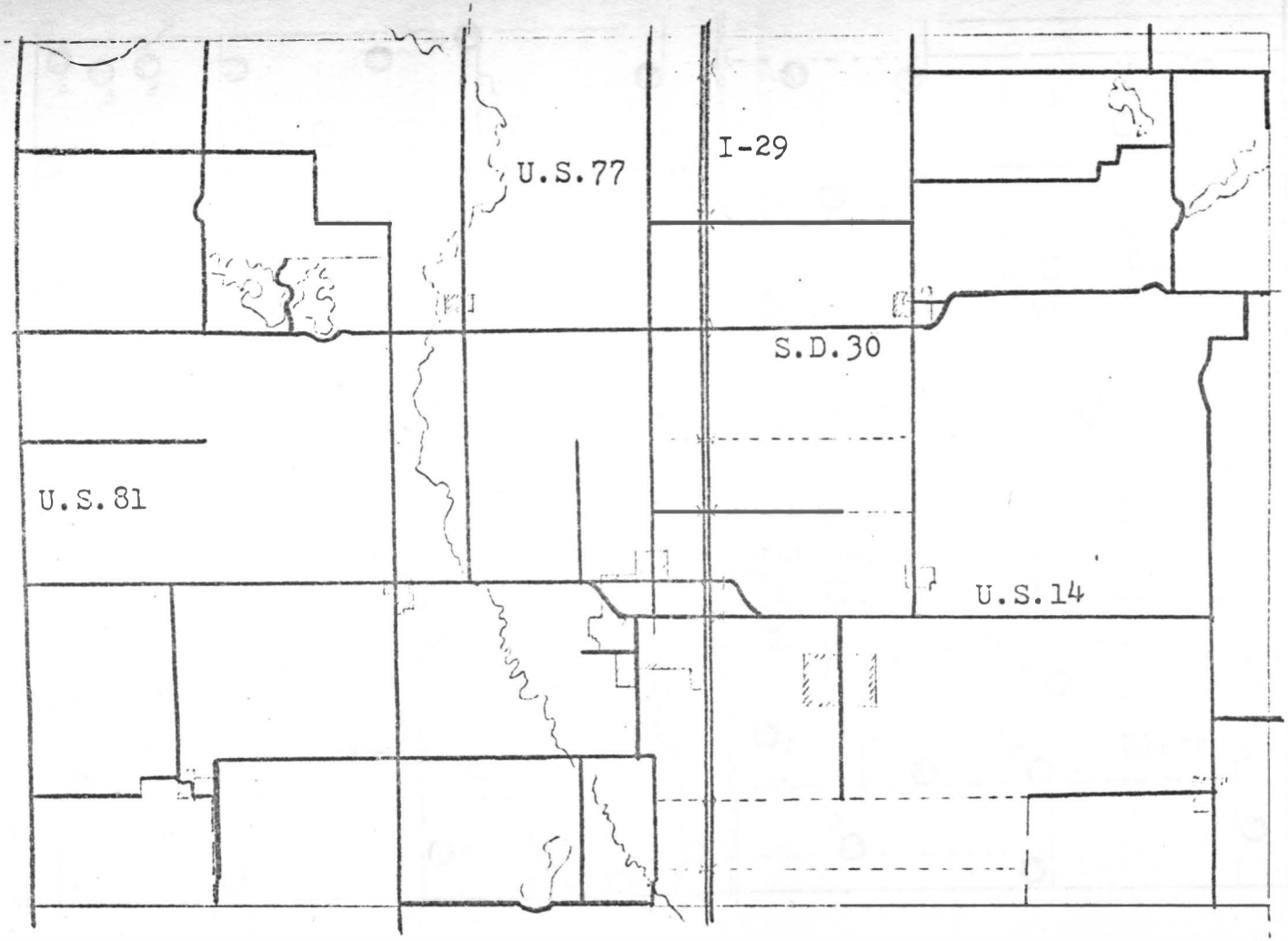

Figure 3: Hard-surfaced Roads in Brookings County.

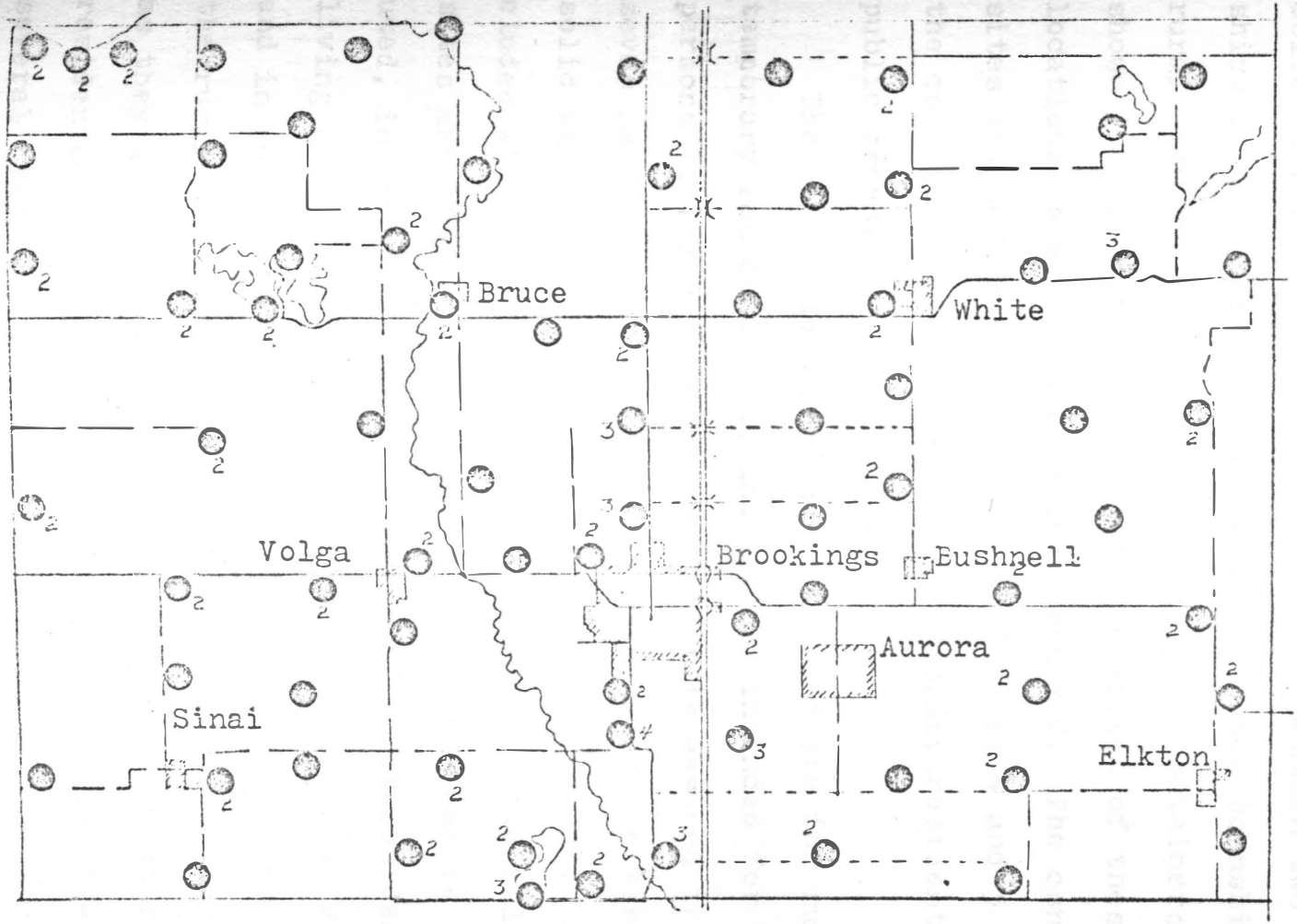

Figure 4: Location of Rural Collection Sites for Four-Cubic Yard Containers, Brookings County.

listed in Appendix D for the years 1970 to 2000. Any collection site located on the border between two townships is considered to be one-half in each township. A rural site system designed for six-yard containers is shown in Figure 5. A more detailed layout of these locations is also included in Appendix C. The container sites and number of containers in Figures 4 and 5 include the containers required for the temporary residents and public areas.

The sites shown in Figures 4 and 5 are for rural and temporary residents only and are not intended for use by persons living within the towns. It is assumed that the seven small towns will provide separate collection of their solid wastes and therefore, these quantities are not included with the rural quantities. Many of the collection sites are located adjacent to towns. This can be attributed, in part, to the large number of rural residents living near towns in housing developments, rural acreages and in rural trailer courts. Also, it is convenient for the rural residents to deposit their waste at these sites as they drive into towns. It is common for most rural residents to go to these towns for pleasure or business several times per week.

The examples shown in detail using four- and six-cubic yard containers are only two of the many possible

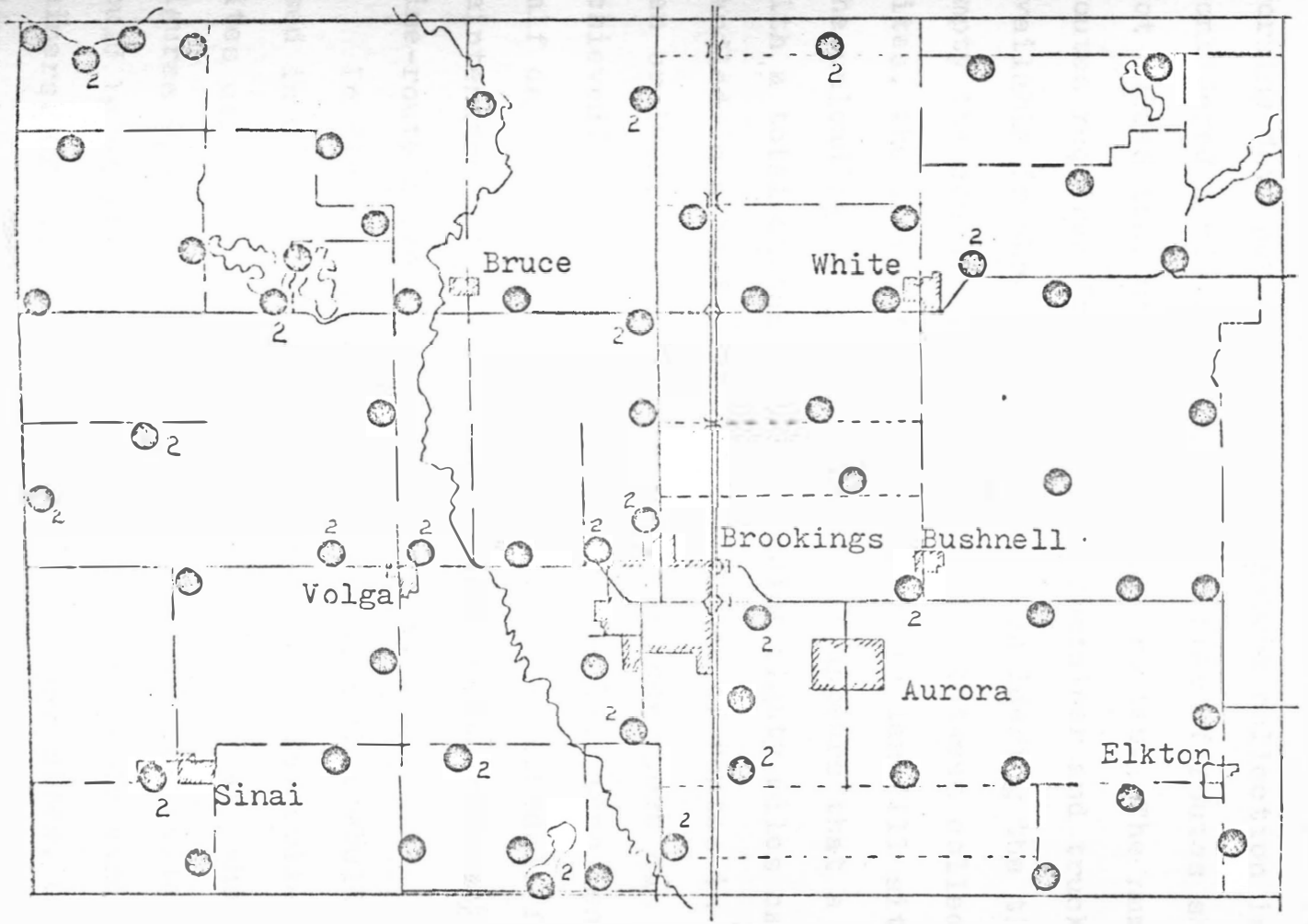

Figure 5: Locations of Rural Collection Sites for Six-Cubic Yard Containers, Brookings County.

solutions. The two considered above appear to best fit the particular rural situation. Since there are five working days per week and once-a-week collection is considered a minimum, the total number of routes should not exceed ten, using one-half day routes. The number of routes required for the various container and truck sizes available is shown in Table 21. Considering the time to empty the container, the travel time between collection sites, the travel time to and from the landfill site and the unloading time of the truck, it appears that a route with a total distance not exceeding eighty miles can be handled in a half day. If the number of routes is held to ten or less, the one collection per week cycle can be achieved. If the number of routes is less than ten, one-half day could be included in the weekly schedule for maintenance and repair. It would seem, therefore, that a nine-route system would be advisable.

In Figures 6, 7 and 8, nine routes that could be used in collection of solid waste from rural collection sites utilizing four-cubic yard containers are shown. Figures 9, 10 and 11 include layouts of nine routes that could be utilized for collection of six-cubic yard containers. Of the four-cubic yard container sites, 62 are adjacent to hard-surfaced roads and 14 are along gravel roads. Of the six-cubic yard container sites, 55 are next

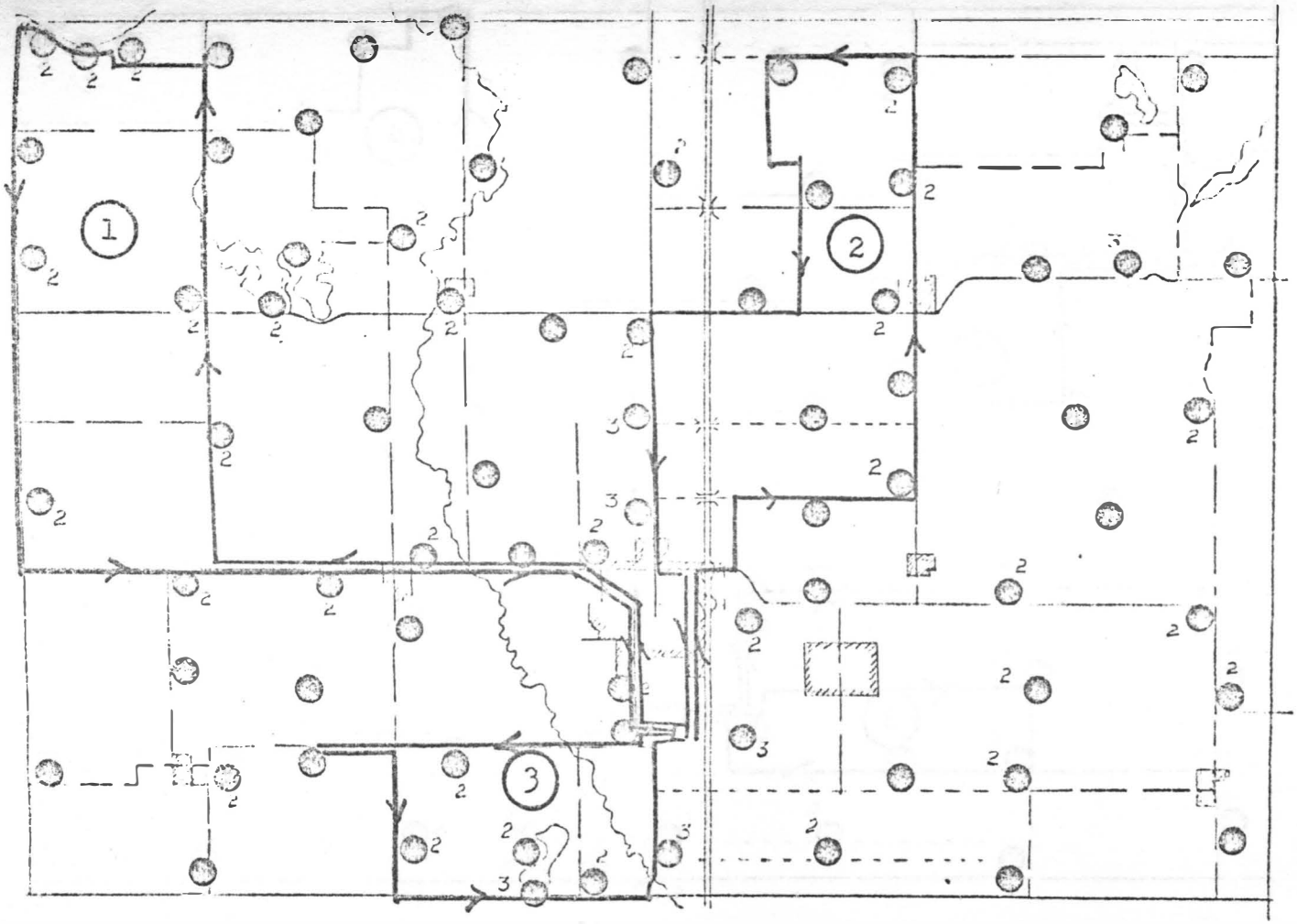

Figure 6: Routes One, Two and Three for Collection of Solid Waste from Four-Cubic Yard Containers.

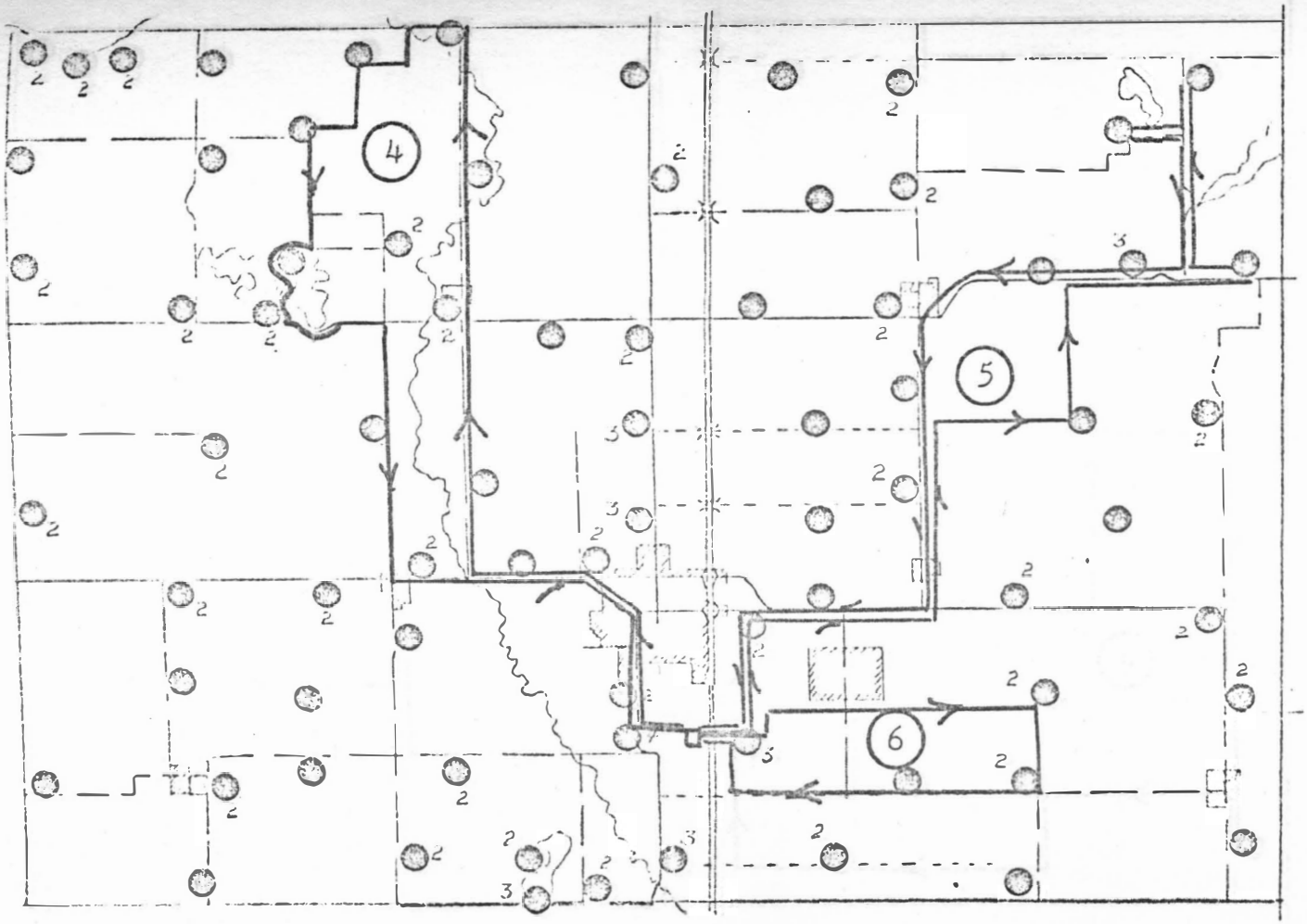

Figure 7: Routes Four, Five and Six for Collection of Solid Waste from Four-Cubic Yard Containers.

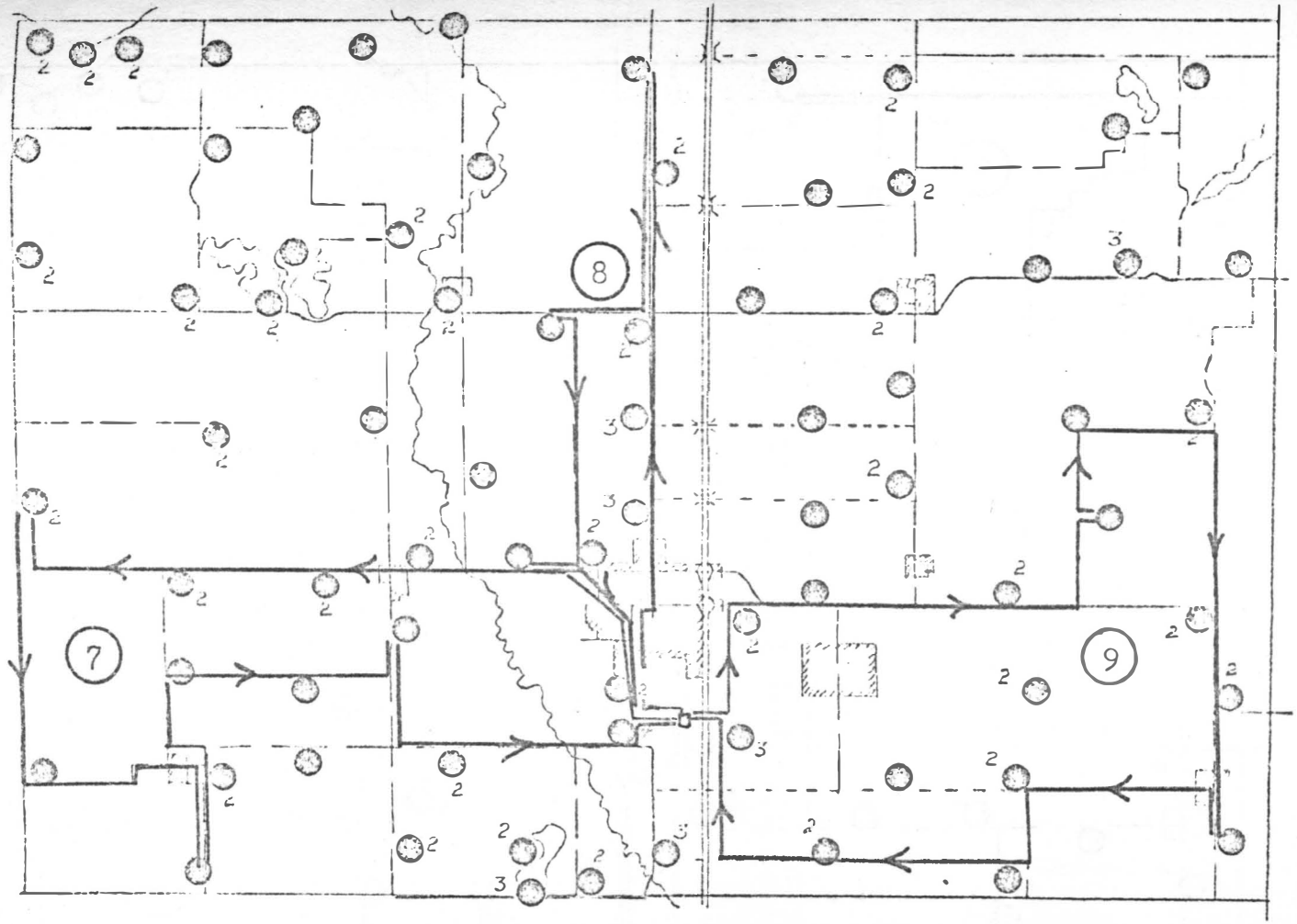

Figure 8: Routes Seven, Eight and Nine for Collection of Solid Waste from Four-Cubic Yard Containers.

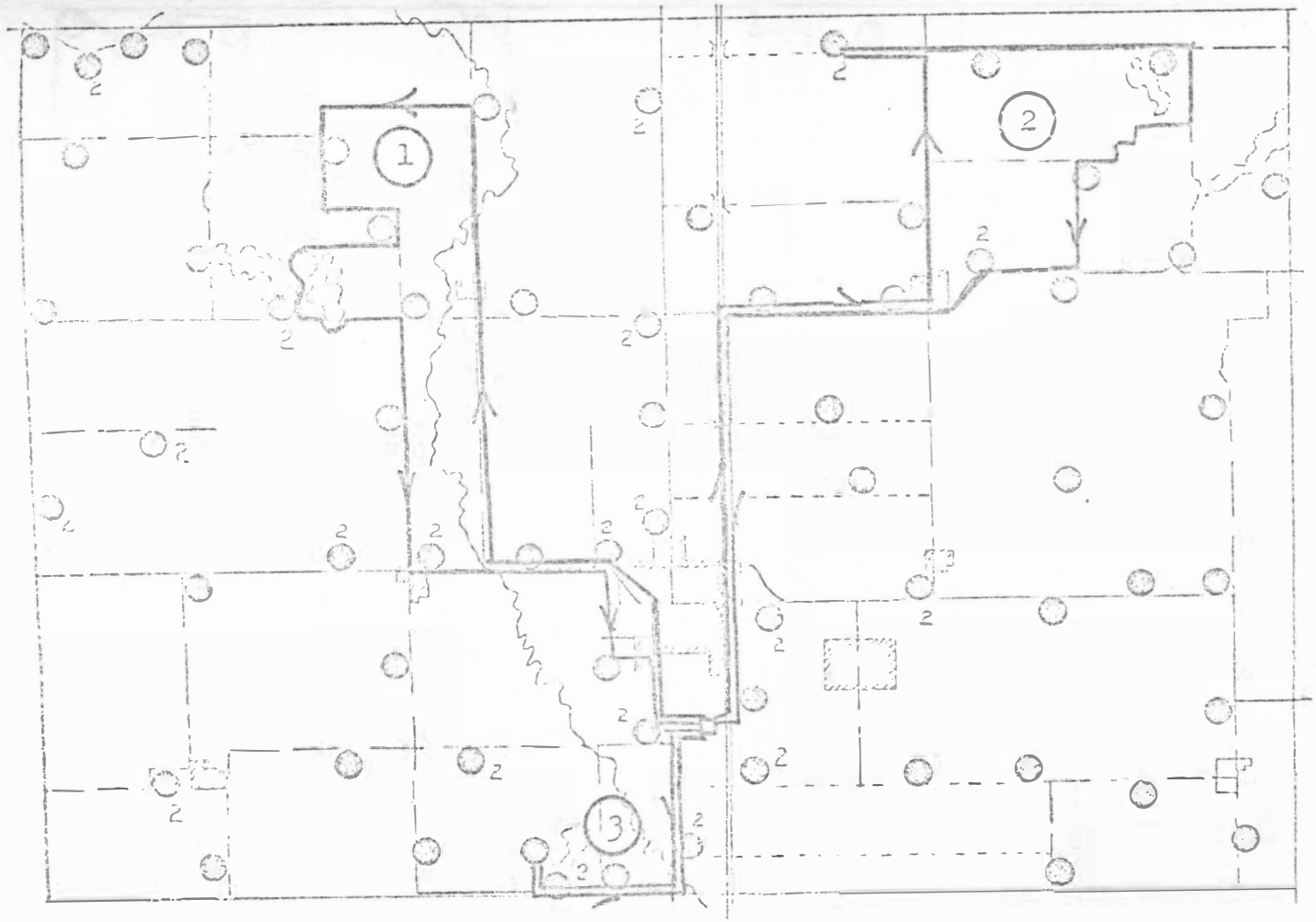

Figure 9: Routes One, Two and Three for Collection of Solid Wastes from Six-Cubic Yard Containers.

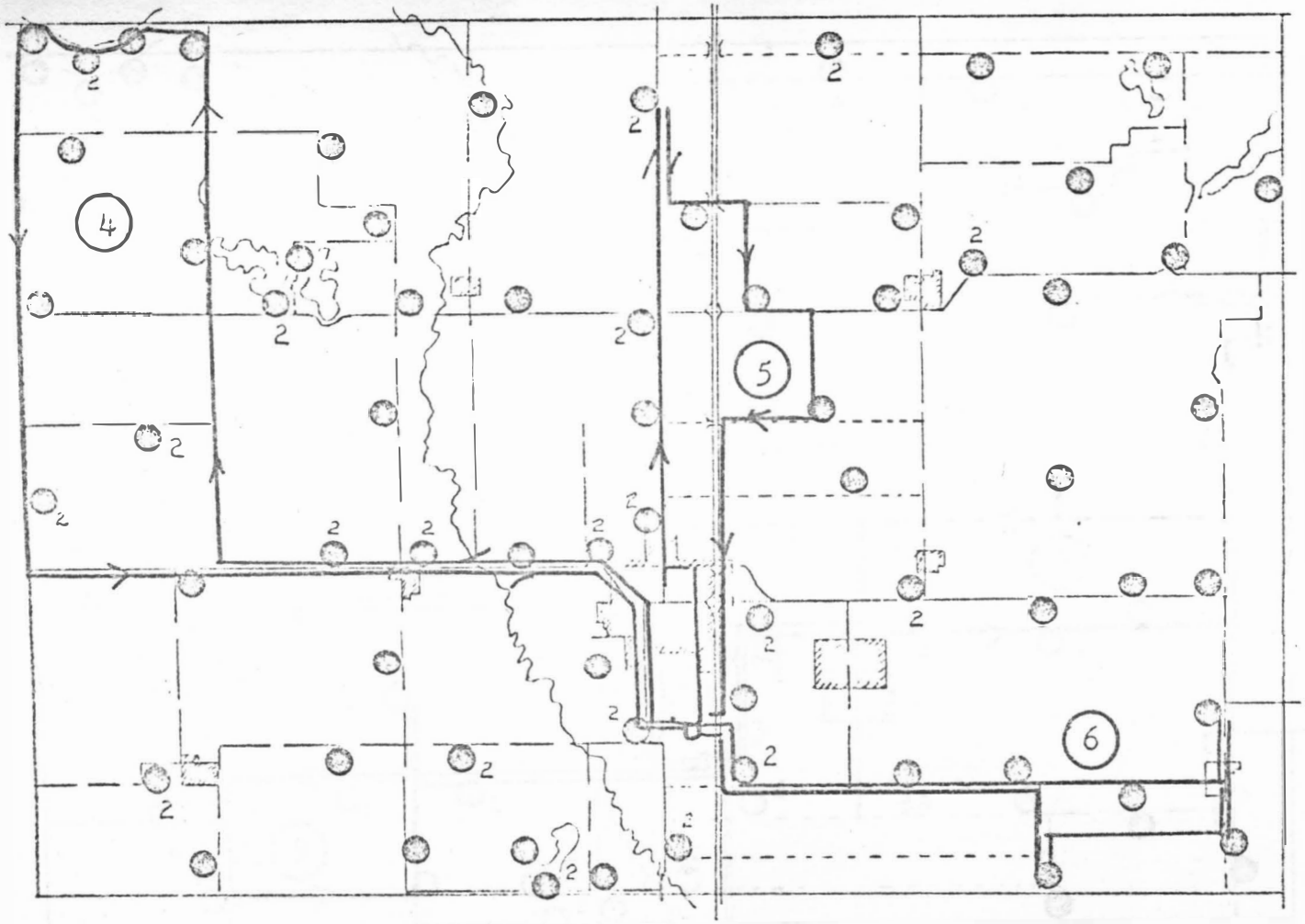

Figure 10: Routes Four, Five and Six for Collection of Solid Waste from Six-Cubic Yard Containers.

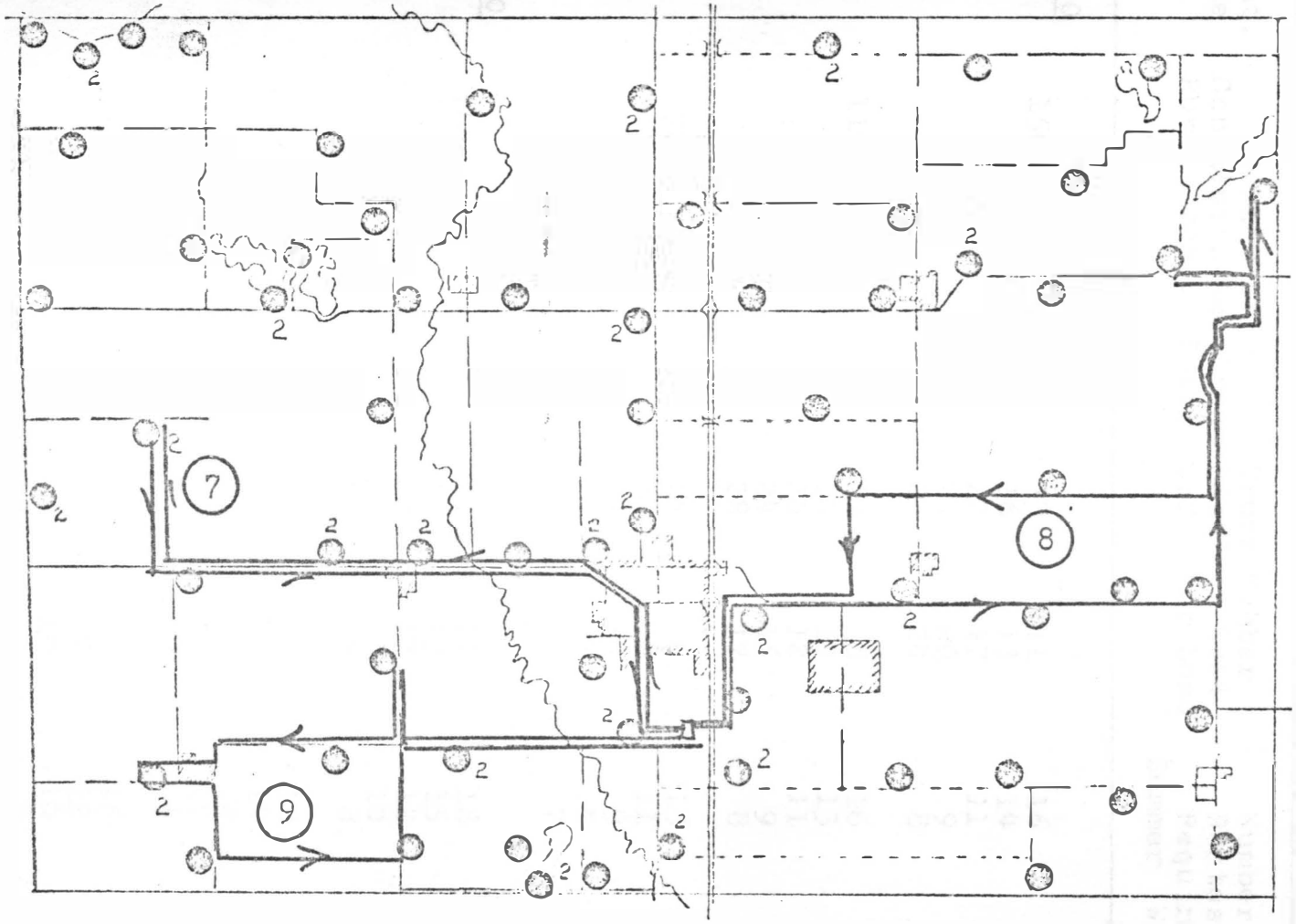

Figure 11: Routes Seven, Eight and Nine for Collection of Solid Waste from Six-Cubic Yard Containers.

Table 21: Number of Routes Required for Various Container and Truck Sizes, 1970 to 2000.

Cont. Size	Number of Containers Required			Truck Size C.Y.	Number of Cont. Per Load	Number of Routes Required	
	Rural	Temp.	Total			Summer	Winter
1970							
3	156	18	174	13	11	16	14
				16	13	14	12
				20	17	11	10
				24	20	9	8
				28	24	8	7
4	116	14	130	13	8	16	15
				16	10	13	12
				20	12	11	10
				24	15	9	8
				28	17	8	7
6	78	9	87	16	6	15	13
				20	8	11	9
				24	10	9	8
				28	12	8	7
				30	13	7	6
1980							
3	164	25	189	13	11	18	15
				16	13	15	13
				20	17	12	10
				24	20	10	9
				28	24	8	7
4	121	19	140	13	8	18	16
				16	10	14	12
				20	12	12	10
				24	15	10	8
				28	17	9	7
6	81	13	94	16	6	16	14
				20	8	12	10
				24	10	10	8
				28	12	8	7
				30	13	8	7

Table 21: Continued, Number of Routes Required for Various Container and Truck Sizes, 1970 to 2000.

Cont. Size	Number of Containers Required Rural	Temp.	Total	Truck Size C.Y.	Number of Cont. Per Load	Number of Routes Required Summer	Winter
1990							
3	167	34	201	13	11	19	16
				16	13	16	13
				20	17	12	10
				24	20	10	9
				28	24	9	7
4	126	26	152	13	8	19	16
				16	10	15	13
				20	12	13	11
				24	15	11	9
				28	17	9	8
6	85	17	102	16	6	17	15
				20	8	13	11
				24	10	11	9
				28	12	9	7
				30	13	8	7
2000							
3	172	47	219	13	11	20	16
				16	13	17	14
				20	17	13	10
				24	20	11	9
				28	24	10	8
4	129	35	164	13	8	21	17
				16	10	17	13
				20	12	14	11
				24	15	11	9
				28	17	10	8
6	87	23	110	16	6	19	15
				20	8	14	11
				24	10	11	9
				28	12	10	8
				30	13	9	7

to hard-surfaced highways and 11 are along graveled roads. Two routes would be run per day with the extra half day used in maintenance.

From Table 21, it can be seen that in order to operate a four-yard collection system in nine routes, a twenty-four cubic yard packer truck would be required. This size truck has a compacted capacity equal to 15 four-cubic yard containers. The routes shown start and finish at the Brookings City landfill. A more detailed description of these routes will be noted. Route One, for example proceeds west of Brookings on U.S. 14 and then northward on a County gravel road and a hard-surfaced County road to a point near Lake Poinsett collecting refuse from six containers at four sites. The route then turns west along the south side of Lake Poinsett collecting from six containers at three sites, several of which would be used by the temporary residents along Lake Poinsett. The route then proceeds south on U.S. Eighty-one to the junction of U.S. 14, collecting from three more containers at two sites. The truck is now loaded and returns to the landfill by U.S. 14. The entire route has covered about 73 miles. A similiar narative of each route could be given, but would resemble the one just mentioned. The routes vary in length from approximately 24 miles to 73 miles with an average for all routes of 52 miles. Since each route must be covered in a half day, a short

route and a long route could be matched for a full day. The summary of route lengths can be found in Table 22.

Table 22: Approximate Length of Routes for Four-Cubic Yard and Six-Cubic Yard Container Collection.

Route Number	Four-Yard Containers Figure Number	Four-Yard Containers Length Miles	Six-Yard Containers Figure Number	Six-Yard Containers Length Miles
1	6	73	9	60
2	6	52	9	65
3	6	30	9	24
4	7	63	10	73
5	7	66	10	45
6	7	24	10	42
7	8	64	11	46
8	8	44	11	64
9	8	56	11	44
Average		52		51

All that would be required to increase collection to twice weekly would be the addition of one truck and crew. The added truck would also provide a backup truck for the once-a-week collection schedule. The second truck should be considered a necessity to either system, and if not purchased initially, should be added as soon as possible. If the two trucks were used initially a substantial reduction in the number of required containers would be realized. This reduced cost would help offset the price of a second truck. The number of sites would not be reduced appreciably using two trucks, because the sites are located to minimize the haul distance of the rural users.

Cost Estimate for Rural Collection System

The cost estimate of this rural collection system can be divided into two parts; the original or construction cost and the operating cost. The original cost can further be broken down into equipment cost and site cost.

The selected rural collection points are all located adjacent to highways, usually at a junction of two roads. These sites, typically, would be one acre in size with dimensions of 120 by 363 feet. The sites should be enclosed with a fence.

A summary of the estimated annual costs of the rural collection system is presented in Table 23. A detailed cost estimate is included as Appendix E. The costs have been estimated for both a four-cubic yard container route and a six-cubic yard container route. The side-loading packer truck is used with the four-cubic yard containers and the front-loading packer truck is used with the larger six-cubic yard containers. The cost of the sites has been spread over a twenty year period to arrive at an annual cost. The interest on the land investment is also included as an annual cost. The annual cost of the truck is based on a five-year truck life and a nominal salvage value at the end of that period. The containers have a life expectancy of eight years with no salvage value anticipated because of the hard use the containers are expected to receive.

Table 23: Summary of Estimated Annual Costs of Rural Solid Waste Collection System.

Item	Annual Cost 4 Cubic Yard Container System	Annual Cost 6 Cubic Yard Container System
Container Site, Acquisition and Development (Appendix E-2)	$26,892	$23,353
Truck (Appendix E-5)	4,700	5,640
Containers (Appendix E-5)	5,200	4,940
Garage Facilities (Appendix E-5)	346	346
Operating Expense (Appendix E-6)	9,986	10,058
Labor, Overhead, Etc. (Appendix E-4)	18,790	11,025
Total Collection Cost	$65,914	$55,362
Landfill User Cost	3,042	3,042
Total Annual Cost	$68,956	$58,404
Additional Cost for Second Truck and Twice-a-week Collection	33,476	26,723
Deduct for Using Fewer Containers	- 1,440	- 1,440
Total Route Cost for Twice-a-week Collection	$100,992	$83,687

The total annual cost of the rural collection system also includes the operating and labor costs. The landfill users charge is based on a per load charge of twice that presently made by the City of Brookings. The total annual cost of operating a four-cubic yard container system, with one truck, is estimated at $68,956. The annual cost for a

six-cubic yard container system with a front loading truck is $58,404. The addition of a second truck to each system would increase the cost to $100,992 and $83,687, respectively.

The user cost is shown in Table 24 for both systems. The user is considered to be one rural living unit, either a farmstead with one residence or an individual rural home. The number of individual users was estimated from Table 2 for rural residents and from Table 15 for temporary lake residents. Based on a total number of users of 1678 units, a monthly charge of $2.90 per unit would be required for a once-a-week collection system using six-cubic yard containers. If temporary residents were charged for six months collection from April through September, the cost per unit could be reduced to $2.74 per month.

Table 24: Estimated User Cost for Solid Waste Collection from Rural Areas of Brookings County.

Type of Service	Cost per Unit per Month
Rural Residents Only	
4 Cubic Yard Containers, Once-a-week Collection	$3.42
6 Cubic Yard Containers, Once-a-week Collection	2.90
4 Cubic Yard Containers, Twice-a-week Collection	5.02
6 Cubic Yard Containers, Twice-a-week Collection	4.16
Rural Residents and Temporary Residents	
4 Cubic Yard Containers, Once-a-week Collection	3.24
6 Cubic Yard Containers, Once-a-week Collection	2.74
4 Cubic Yard Containers, Twice-a-week Collection	4.75
6 Cubic Yard Containers, Twice-a-week Collection	3.93

The City of Brookings presently charges $2.00 per month for solid waste collection. The estimated charge per unit for rural collection compares favorably with this charge.

Estimated Quantities to be Hauled to Landfill Site

The total estimated volume of solid waste hauled to the sanitary landfill from the various sources is shown in Table 25. It has been estimated that the present landfill site used by the City of Brookings will last until the year 2000 if used at the present rate of fill. The solid waste from rural areas and the seven small towns would increase the total volume presently being hauled to the Brookings Site by an estimated 26 percent. Thus, assuming that the previous rate of increase continues, the expected life of the Brookings City landfill would be shortened about eight years.

A future landfill site would have to be developed to receive waste after the year 1992. This site should be purchased at least five years prior to use to allow adequate time for site acquisition, preparation and development. The site should be large enough to accomodate its users for at least twenty-five to thirty years. If the future rate of use is the same as that predicted for the year 2000, the new site would receive an estimated 3,364,000 cubic yards of solid waste over a period of thirty years.

Based on a compacted overall depth of nine feet, a total area of 233 acres would be required. Space for buildings, roads and trees could increase this total to 240 acres. If future development was also considered, 320 acres could be acquired.

Table 25: Estimated Volume of Solid Waste Added to Sanitary Landfill, 1970 to 2000.

Year	Volume of Solid Waste per Year, Cubic Yards				
	City of Brookings	Seven Small Towns	Rural Areas	Temporary Residences	Total
1970	23,855	4,537	4,719	542	33,653
1980	35,968	5,452	4,945	744	47,109
1990	52,533	6,606	5,086	1,021	65,246
2000	76,006	8,104	5,203	1,404	90,717
Total for Ten Year Period					
1970-1980	299,115	49,945	48,320	6,430	403,810
1980-1990	442,505	60,290	50,155	8,825	561,775
1990-2000	642,695	73,550	51,445	12,125	779,815
1970-2000	1,384,315	183,785	149,920	27,380	1,745,400

The fill in the landfill is compacted to a density of 900 pounds per cubic yards(9).

Future Sanitary Landfill Site Selections

Although the county-wide collection system could utilize the present Brookings City site until the capacity of this landfill has been exhausted and then jointly secure and develop a new site, the County could instead purchase a sanitary landfill site for its rural system initially and not use the City of Brookings landfill. If this latter approach were adopted, it would be desirable to acquire the site at least five years prior to actual beginning of landfill so that grading, fencing, tree planting and road construction could be accomplished satisfactorily. Either option will require a new landfill site at some time in the future. If a county landfill is the method used, the land would be needed now. If the City of Brookings would be involved, the new site would have to be purchased by 1987.

The location for a new landfill should be chosen considering all factors, such as soil conditions, neighboring land use, drainage, topography and future planning or zoning. Several soil types exist in Brookings County that would be suitable for sanitary landfill purposes. The location of these soils may be found on a soils map prepared by the United States Department of Agriculture(2). A description and evaluation of soil conditions for various uses, including use for sanitary landfills was also made(23). This report covers the major soils found in Brookings

County and the limitations of each type. A limitation does not mean the soil is excluded for a specific use, but merely that more facts are needed regarding the particular soil. According to the report, the following soils have only slight limitations for use as sanitary landfills. These are Buse (Bc), Buse (Bd), Moody (Md,Me), Vienna (Va,Vb,Vd) and Vienna (Vc). A close check of the Soil Survey of Brookings County(2) reveals several locations within the County where these soils exist that could be utilized as future landfill sites. The type of landfill for which suitability was evaluated was the trench type with the excavated soil material to serve as a cover(23). The normal soil survey was to a depth of five to six feet. If a trench is to be cut to a greater depth, further geological investigation would be needed. Also included in the evaluation were consideration of such data as depth to water table, soil drainage, flooding, permeability, soil slope, texture, and depth to sand or gravel. The ratings in the report(23) were not made for area-type landfills where refuse is layered on the surface. While the report(23) does not consider detailed site selection, general areas can be selected and cost of each estimated from the selection. A detailed study of these general areas would have to be made prior to acquisition. Some factors, in addition to those previously mentioned, that should be considered would be cost, availability of land, adjacent roads, and adjacent land

use, as well as the overall adaptability of the area to a landfill site.

Based on the study of the soils adjacent to Brookings and a review of the overall soils and topography(2)(23), it is evident that there are several possible sites suitable for a future sanitary landfill. The locations are listed in Table 26 by section and township and shown on Figure 12. Based on the above criteria the best area for a landfill would be the general area enclosing sites nine through 14 on Figure 12. A detailed study would be needed prior to selecting the actual site.

Table 26: Possible Sites for Sanitary Landfill in Brookings County.

Reference No. Figure 12	Location Township	Section	Soil Type(2)(23) Major	Other
1	Volga	W½, 17	Bd,Bc	Oc,Pa
2	Sterling	E½, 19	Va,Vb	Ld,Ec
3	Sterling	E½, 6	Va,Vb,Bd	Lc,Fm
4	Sterling	W½, 5	Va,Vb,Vc	Bd
5	Afton	N½, 2	Va,Vb	Ld,Lc,Ac
6	Afton	S½, 23	Va,Vb	Ld
7	Afton	N½, 26	Va	Ld
8	Sherman	All 32	Va,Vb	Vc,Be,Fm
9	Alton	E½, 3	Vb,Vc,Va	Ld,Bd,Fe
10	Alton	E½, 9	Vb,Va,Vd	Ld
11	Alton	N½, 10	Va,Vb	Ld
12	Alton	N½, 11	Va,Vc,Me	Ld
13	Alton	S½, 15	Va,Vb,Vc	
14	Alton	W½, 14	Va,Vb,Vc	

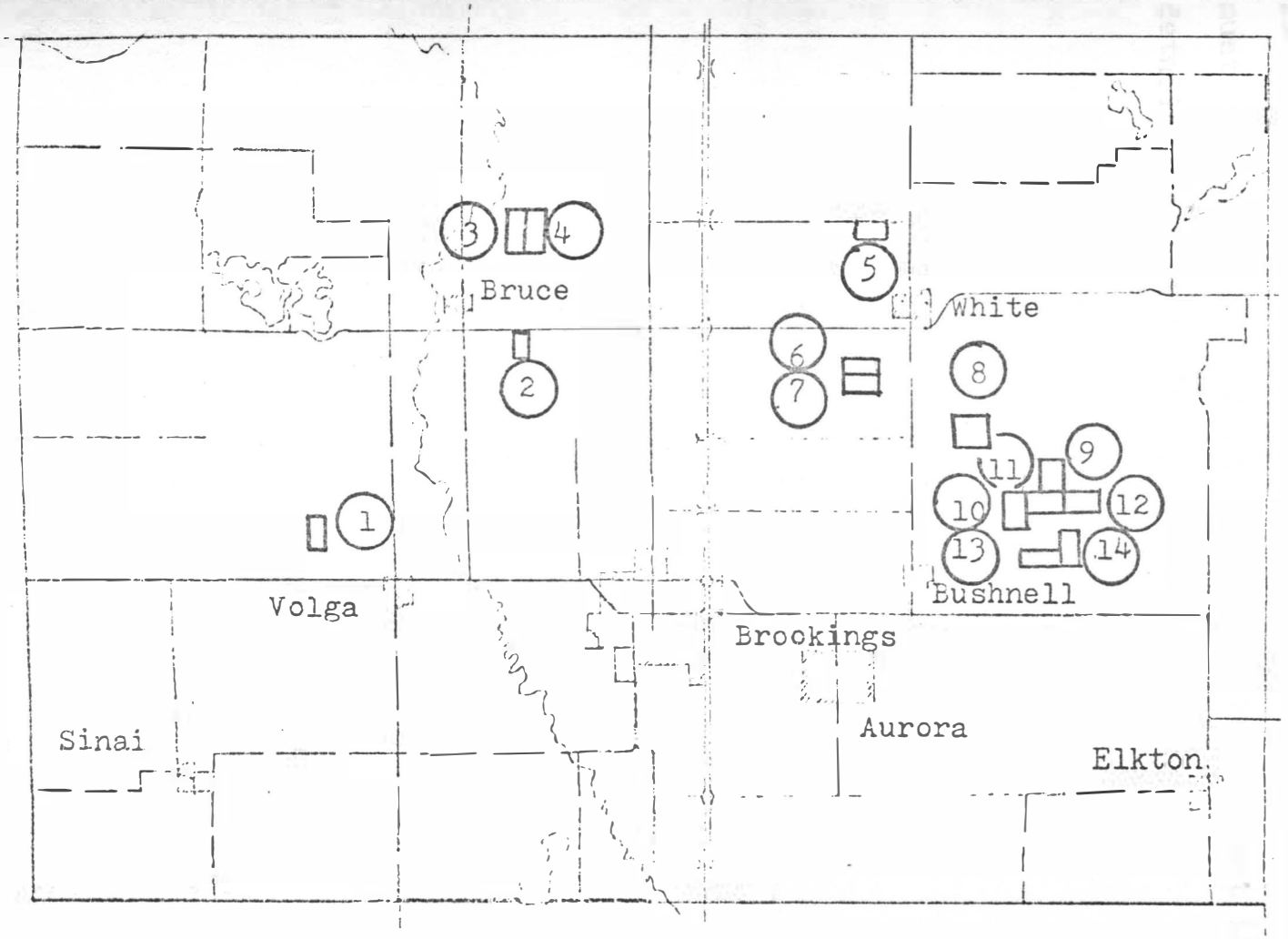

Figure 12: Possible Locations of Future Sanitary Landfill Sites in Brookings County.

The building of a new sanitary landfill must follow the zoning ordinance adapted by the Brookings County Zoning Commission in March, 1971(24). The procedure that must be followed in obtaining an operating permit is detailed in Section 995, Page 43(24).

SUMMARY AND CONCLUSIONS

The passage of the Solid Waste Act and the Air Pollution Control Act has made it imperative that some system of solid waste control be devised for rural areas. The ban on burning in open dumps and the requirement of a sanitary landfill for disposal has resulted in the closing of the many open dumps in the County. The seven small towns have had to either operate their own sanitary landfill or make arrangements to use the City of Brookings landfill. It is rather costly for the seven towns to operate their own sanitary landfill when compared with the alternative of hauling the solid waste to the Brookings City landfill or using a Countywide landfill.

The closing of the many open dumps in the County not only affects the residents of the small towns, but also imposes a severe problem for the rural residents. In the past, these rural residents hauled to the closest dump or used their own, as evidenced by the many small promiscuous dumps throughout the County.

The overall objective of this study was to propose a feasible solution to the solid waste problem of the rural area of Brookings County. To date most studies have been made for the large municipalities and there is a lack of information on rural solid waste collection. Quantities of solid waste per capita found in previous studies were

used along with the census or estimated future populations to obtain the total quantity of solid waste from the rural areas of the County for the years 1970, 1980, 1990 and 2000.

The building of solid waste collection sites throughout the County and then transporting the refuse from these sites to a central sanitary landfill appeared to be the most feasible solution. The collection sites were located throughout the County and spaced so that all rural residents would not have to transport their waste a distance over four miles. Containers of four to six cubic yards in capacity would be used at each site as depositories for the refuse. A compactor truck would then collect on a weekly or biweekly basis and haul the refuse to a sanitary landfill. Proposed routes were laid out utilizing four to six cubic yard containers at local sites.

The existing landfill owned by the City of Brookings is adequate for the present time, however, thought should be given to the purchase of land for a Countywide sanitary landfill within fifteen years.

It is the conclusion of this author that a collection system be established in the near future for the rural residents of the County utilizing community collection sites. The cost of this system of less than $3.00 per month per living unit is reasonable and should prove no hardship to the rural population. This system should be

Countywide and should include all towns, summer homes at the lakes, farms and rural living units. It is also the conclusion that the system be administered by the County or a County approved governmental agency.

RECOMMENDATIONS

Based on the results of this study, the following recommendations are made:

1. A complete cost analysis of the rural solid waste collection and disposal system should be made. This analysis would include the original cost, the maintenance cost and the method of paying for the system.
2. Prior to the purchase of a new landfill site, a complete study should be made to determine the location. The study should include soil types, water conditions, topography, environmental impact, and method of operation.

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APPENDIX A

Population Study and Forecast for Brookings County and for the Towns and Townships in the County.

The population of the various segments of Brookings County was studied and a population forecast for each was made. Several methods of population forecasting were used: graphical comparison, straight line projection, arithmetic progression and geometric progression. The values found by these methods were averaged and the results used as the predicted population. This method was used for the City of Brookings, each of the seven small towns and for the rural townships as a whole. The value for the townships was prorated back to each individual township to forecast a future population of each township. All of the townships show a declining population with the exception of Medary and Brookings which are growing because of new rural residential developments. The values found by each method are shown in the following figures and tables. These tables also show the various factors used in the different methods of population estimating.

Table A-1: Population of Brookings County and Its Subdivisions, 1900 to 1970(4)

	1970	1960	1950	1940	1930	1920	1910	1900
Towns								
Brookings	13,717	10,558	7,764	5,346	4,376	3,924	2,971	2,346
Aurora	237	232	202	225	166	246	236	-
Bushnell	65	92	96	134	134	350*	-	-
Elkton	541	621	657	779	856	872	742	578
White	418	417	525	559	533	594	468	454
Bruce	217	272	305	394	371	342	262	-
Sinai	147	166	181	182	217	216	-	-
Volga	982	780	578	632	604	600	568	396
Total Small Towns	2,607	2,580	2,544	2,905	2,881	3,220	2,276	1,428
Total All Towns	16,324	13,138	10,308	8,251	7,257	7,144	5,247	3,774
Townships								
Afton	235	272	294	349	398	411	367	359
Alton	258	334	348	359	386	146	494	426
Argo	211	264	302	332	364	385	400	399
Aurora	290	283	308	365	425	390	424	569
Bangor	234	314	332	429	505	517	389	265
Brookings	398	523	479	382	446	373	303	298
Elkton	148	190	212	213	257	229	243	304
Eureka	215	259	315	388	407	442	383	377
Lake Hendricks	185	284	311	343	386	403	436	434
Laketon	203	302	298	319	437	423	417	420
Lake Sinai	226	266	333	448	499	516	597	555
Medary	508	359	369	387	439	352	333	348
Oak Lake	233	292	373	390	470	428	370	424
Oakwood	226	256	306	317	363	373	288	356
Oslo	260	367	375	426	480	536	514	508
Parnell	227	260	295	415	426	420	387	426
Preston	239	302	324	346	422	361	376	291

Table A-1: Continued, Population of Brookings County and Its Subdivisions, 1900 to 1970(4).

	1970	1960	1950	1940	1930	1920	1910	1900
Richland	203	240	298	298	348	247	321	318
Sherman	178	226	278	306	403	376	329	267
Sterling	304	321	344	404	469	394	447	392
Trenton	273	316	319	347	403	363	356	352
Volga	324	365	420	444	490	506	437	383
Winsor	256	313	310	302	367	384	320	316
Total Rural	5,834	6,908	7,543	8,309	9,590	8,975	8,931	8,787
Total County	22,158	20,046	17,851	16,560	16,847	16,119	14,178	12,561

Table A-2: Summary of Population Estimates for Towns and Rural Areas of Brookings County

	Graphical Comparison	Arith. Prog.	Geom. Prog.	Straight Line Proj.	Average of all Methods
1980					
Brookings	17,600	17,352	17,387	16,600	17,235
Aurora		238	242	238	239
Bushnell		46	46	45	46
Elkton		428	453	462	448
White		410	414	419	414
Bruce		163	164	160	162
Sinai		127	128	126	127
Volga		1,181	1,162	1,185	1,176
Rural		4,725	5,020	4,929	4,890
Total					24,737
1990					
Brookings	21,200	21,516	21,720	19,500	20,984
Aurora		237	244	243	241
Bushnell		32	32	26	30
Elkton		336	374	383	364
White		401	407	420	409
Bruce		119	120	105	115
Sinai		108	109	108	108
Volga		1,370	1,357	1,390	1,372
Rural		3,756	4,302	4,026	4,028
Total					27,651
2000					
Brookings	25,200	26,573	27,001	22,400	25,293
Aurora		235	254	245	245
Bushnell		22	22	8	17
Elkton		263	306	305	291
White		392	398	420	403
Bruce		85	86	52	74
Sinai		91	91	90	91
Volga		1,555	1,572	1,595	1,574
Rural		2,975	3,699	3,225	3,301
Total					31,289

Table A-3: Population by Graphic Comparison, City of Brookings

Year	Brookings, S. Dak.	Ames, Iowa	Fargo, N. Dak.	Aberdeen, S. Dak.	Mankato, Minn.	Grand Island, Nebr.	St. Cloud, Minn.	Grand Forks, N. Dak.
1900	2,346	2,422	9,589	4,087	10,599	7,554	8,663	7,652
1910	2,971	4,223	14,331	10,753	10,365	10,326	10,600	12,478
1920	3,924	6,270	21,961	14,537	12,469	13,947	15,873	14,010
1930	4,376	10,261	28,619	16,465	14,038	18,041	21,000	17,112
1940	5,346	12,555	32,580	17,015	15,654	19,130	24,173	20,228
1950	7,764	22,898	38,256	21,051	18,809	22,682	28,410	26,836
1960	10,558	27,003	46,662	23,073	23,797	25,742	33,815	34,451
1970	13,717	39,505	53,365	26,476	30,895	31,269	39,691	39,008
Estimated Year Each had 13,717	1970	1941	1909	1918	1928	1919	1916	1918

Estimated Population of the City of Brookings From the Graph Using the Above Data as Plotted on Figure A-1.

1980	17,600
1990	21,200
2000	25,200

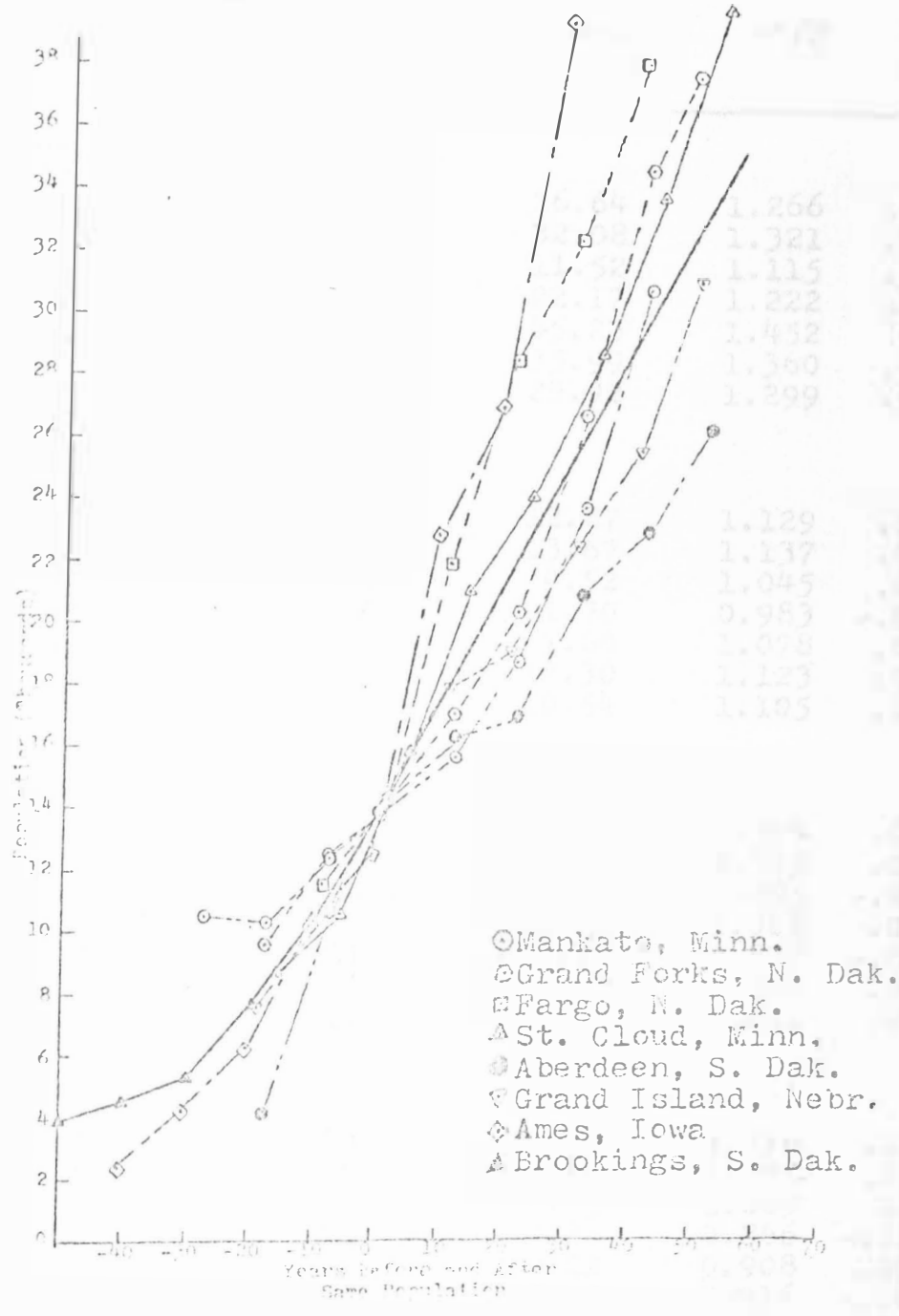

Figure A-1.: Graphical Comparison, City of Brookings.

Table A-4: Factors for Geometric and Arithmetic Progression for Population Estimation.

Year	Population	Increase	Percent Increase	P'/P	"r"
Brookings City					
1900	2,346				
1910	2,971	625	26.64	1.266	.0238
1920	3,924	953	32.08	1.321	.0282
1930	4,376	452	11.52	1.115	.0109
1940	5,346	970	22.17	1.222	.0203
1950	7,764	2,418	45.23	1.452	.0380
1960	10,558	2,794	35.99	1.360	.0312
1970	13,717	3,159	29.92	1.299	.0265
Brookings County					
1900	12,561				
1910	14,178	1,617	12.87	1.129	.0122
1920	16,119	1,941	13.67	1.137	.0129
1930	16,847	728	4.52	1.045	.0044
1940	16,560	- 287	-1.70	0.983	-.0017
1950	17,851	1,291	7.80	1.078	.0075
1960	20,046	2,195	12.30	1.123	.0116
1970	22,158	2,112	10.54	1.105	.0100
Seven Small Towns					
1900	1,428				
1910	2,276	848	59.38	1.594	.0477
1920	3,220	944	41.48	1.415	.0353
1930	2,881	- 339	-10.53	0.895	-.0111
1940	2,905	24	0.83	1.008	.0008
1950	2,544	- 361	-12.43	0.876	-.0132
1960	2,580	36	1.42	1.014	.0013
1970	2,607	27	1.05	1.011	.0011
Rural Brookings County					
1900	8,787				
1910	8,931	144	1.64	1.016	.0016
1920	8,975	44	0.49	1.005	.0005
1930	9,590	615	6.85	1.069	.0067
1940	8,309	-1,281	-13.36	0.866	-.0143
1950	7,543	- 766	- 9.22	0.908	-.0096
1960	6,908	- 635	- 8.42	0.916	-.0088
1970	5,834	-1,074	-15.55	0.846	-.0166

Table A-4: Continued, Factors for Geometric and Arithmetic Progression for Population Estimation.

Year	Population	Increase	Percent Increase	P'/P	"r"
Aurora					
1900					
1910	236				
1920	246	10	4.23	1.0423	.0041
1930	166	- 80	-32,52	0.6747	-.0385
1940	225	59	35.54	1.3554	.0309
1950	202	- 23	-10.22	0.8977	-.0107
1960	232	30	14.85	1.1485	.0139
1970	237	5	2.15	1.0215	.0021
Bushnell					
1900					
1910					
1920	134				
1930	134	0	0.00	0.0	.0
1940	134	0	0.00	0.0	.0
1950	96	- 38	-28.35	0.716	-.0328
1960	92	- 4	- 4.16	0.958	-.0043
1970	65	- 27	-29.34	0.706	-.0342
Elkton					
1900	578				
1910	742	164	28.37	1.284	.0253
1920	872	130	17.52	1.175	.0163
1930	856	- 16	- 1.83	0.982	-.0018
1940	779	- 77	- 8.99	0.910	-.0094
1950	657	- 122	-15.66	0.843	-.0169
1960	621	- 36	- 5.47	0.945	-.0056
1970	541	- 80	-12.88	0.871	-.0137
White					
1900	454				
1910	468	14	3.08	1.030	.0030
1920	594	126	26.92	1.269	.0241
1930	533	- 61	-10.26	0.897	-.0107
1940	559	26	4.87	1.048	.0048
1950	525	- 34	- 6.08	0.939	-.0063
1960	417	- 108	-20.57	0.794	-.0228
1970	418	1	0.23	1.002	.0002

Table A-4: Continued, Factors for Geometric and Arithmetic Progression for Population Estimation.

Year	Population	Increase	Percent Increase	P'/P	"r"
Bruce					
1900					
1910	262				
1920	342	80	30.53	1.305	.0270
1930	371	29	7.81	1.085	.0082
1940	394	23	6.19	1.0619	.0060
1950	305	-89	-29.18	0.7741	-.0253
1960	272	-33	-10.81	0.8918	-.0114
1970	217	-55	-20.22	0.7977	-.0223
Volga					
1900	396				
1910	568	172	43.43	1.4343	.0367
1920	600	32	5.63	1.0563	.0055
1930	604	4	0.66	1.0066	.0006
1940	632	28	4.63	1.0463	.0045
1950	578	-54	- 8.54	0.9145	-.0089
1960	780	202	34.94	1.3494	.0304
1970	982	202	25.89	1.2589	.0233
Sinai					
1900					
1910					
1920	216				
1930	217	1	0.46	1.0046	.0004
1940	182	- 35	-16.12	0.8387	-.0174
1950	181	- 1	- 0.54	0.9945	-.0005
1960	166	- 15	- 8.28	0.9171	-.0086
1970	147	- 19	-11.44	0.8855	-.0121

Table A-5: Values from Graph (Figure A-5) for Geometric Progression for City of Brookings, Brookings County, Rural Brookings County and the Total of the Seven Small Towns.

	Year	"r"	$(1+r)^n$	Population
Brookings	1980	.0240	1.2676	17,387
	1990	.0225	1.2492	21,720
	2000	.0220	1.2431	27,001
County	1980	.0095	1.0992	24,335
	1990	.0090	1.0937	26,615
	2000	.0090	1.0937	29,110
Seven Small Towns	1980	.0010	1.0100	2,633
	1990	.0010	1.0100	2,660
	2000	.0012	1.0121	2,692
Rural	1980	-.0185	0.8296	5,020
	1990	-.0200	0.8170	4,362
	2000	-.0205	0.8129	3,699

Table A-6: Values from Graph (Figure A-2) for Arithmetic Progression for City of Brookings, Brookings County, Rural Brookings County and the Total of the Seven Small Towns.

	Year	Percent Increase	Population
Brookings	1980	26.5	17,352
	1990	24.0	21,516
	2000	23.5	26,573
County	1980	10.0	24,200
	1990	10.0	26,300
	2000	10.0	28,400
Seven Small Towns	1980	- 2.0	2,555
	1990	- 2.0	2,504
	2000	- 2.0	2,454
Rural	1980	-19.0	4,725
	1990	-21.5	3,756
	2000	-21.8	2,975

Table A-7: Population Estimate by Geometric and Arithmetic Progression for the Seven Small Towns in Brookings County.

Year	Geometric Progression "r"	(1+r)n	Population	Arithmetic Progression Percent Increase	Population
Aurora					
1980	.0020	1.0201	242	0.5	238
1990	.0009	1.0009	244	- 0.5	237
2000	.0004	1.0407	254	- 1.0	235
Bushnell					
1980	-.0348	0.7017	46	-30.0	46
1990	-.0351	0.6995	32	-30.8	32
2000	-.0352	0.6988	22	-31.2	22
Elkton					
1980	-.1075	0.8381	453	-20.4	428
1990	-.0190	0.8254	374	-21.4	336
2000	-.0200	0.8170	306	-21.8	263
Bruce					
1980	-.0275	0.7566	164	-24.8	163
1990	-.0305	0.7336	120	-27.0	119
2000	-.0324	0.7193	86	-28.5	85
Sinai					
1980	-.0141	0.8676	128	-13.5	127
1990	-.0160	0.8510	109	-14.9	108
2000	-.0175	0.8381	91	-15.5	91
White					
1980	-.0010	0.9900	414	- 2.0	410
1990	-.0018	0.9821	407	- 2.3	401
2000	-.0022	0.9782	398	- 2.3	392
Volga					
1980	.0170	1.1836	1,162	20.3	1,181
1990	.0156	1.1674	1,357	16.0	1,390
2000	.0148	1.1582	1,572	13.5	1,555
Total Seven Small Towns					
1980			2,609		2,593
1990			2,643		2,603
2000			2,729		2,643

Table A-8: Summary of Estimated Population of the seven Small Towns by Straight Line Projection, Arithmetic Progression and Geometric Progression for 1980, 1990 and 2000.

Year	Geometric Progression	Arithmetic Progression	Straight Line Projection	Average
Aurora				
1980	242	238	238	239
1990	244	237	243	241
2000	254	235	245	245
Bushnell				
1980	46	46	45	46
1990	32	32	26	30
2000	22	22	8	17
Elkton				
1980	453	428	462	448
1990	374	336	383	364
2000	306	263	305	291
Bruce				
1980	164	163	160	162
1990	120	119	105	115
2000	86	85	52	74
Sinai				
1980	128	127	126	127
1990	109	108	108	108
2000	91	91	90	91
White				
1980	414	410	419	414
1990	407	401	420	409
2000	398	392	420	403
Volga				
1980	1,162	1,181	1,185	1,176
1990	1,357	1,370	1,390	1,372
2000	1,572	1,555	1,595	1,574
Total				
1980	2,609	2,593	2,635	2,612
1990	2,643	2,603	2,675	2,639
2000	2,729	2,643	2,715	2,695

Table A-9: Population Estimation for Rural Townships of Brookings County, 1980, 1990 and 2000.

Township	1980	1990	2000
Afton	187	145	109
Alton	207	160	121
Argo	169	131	99
Aurora	233	180	136
Bangor	188	146	110
Brookings	411	424	436
Elkton	119	92	69
Eureka	173	134	101
Lake Hendricks	149	115	87
Laketon	163	126	95
Lake Sinai	181	140	106
Medary	524	541	554
Oak Lake	187	145	109
Oakwood	181	140	106
Oslo	209	162	122
Parnell	182	141	106
Preston	192	149	112
Richland	163	126	95
Sherman	143	111	84
Sterling	241	189	143
Trenton	219	170	128
Volga	260	201	152
Winsor	206	160	121
Total Rural	4,890	4,028	3,301

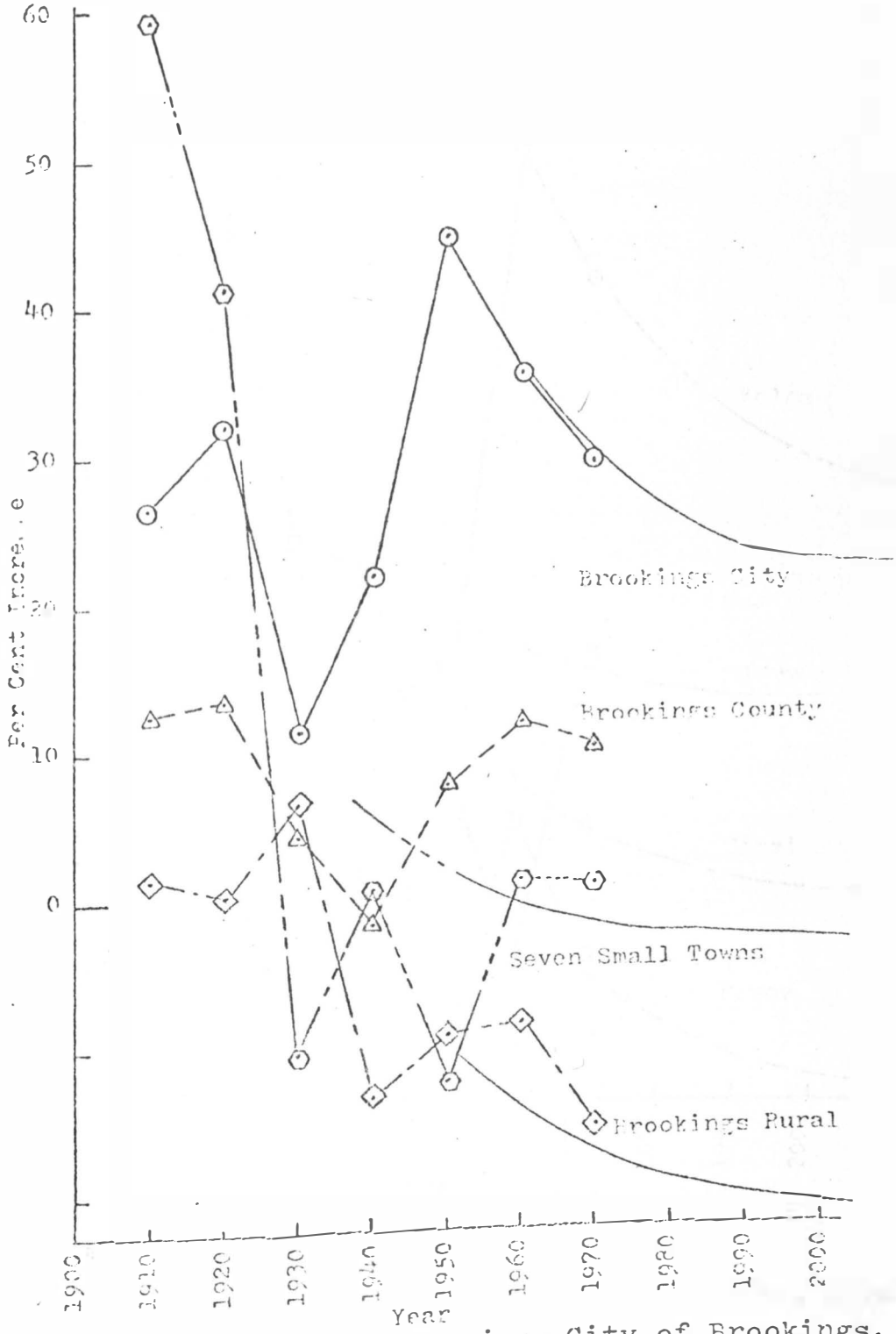

Figure A-2: Arithmetic Progression: City of Brookings, Brookings County, Seven Small Towns, and Rural Brookings County.

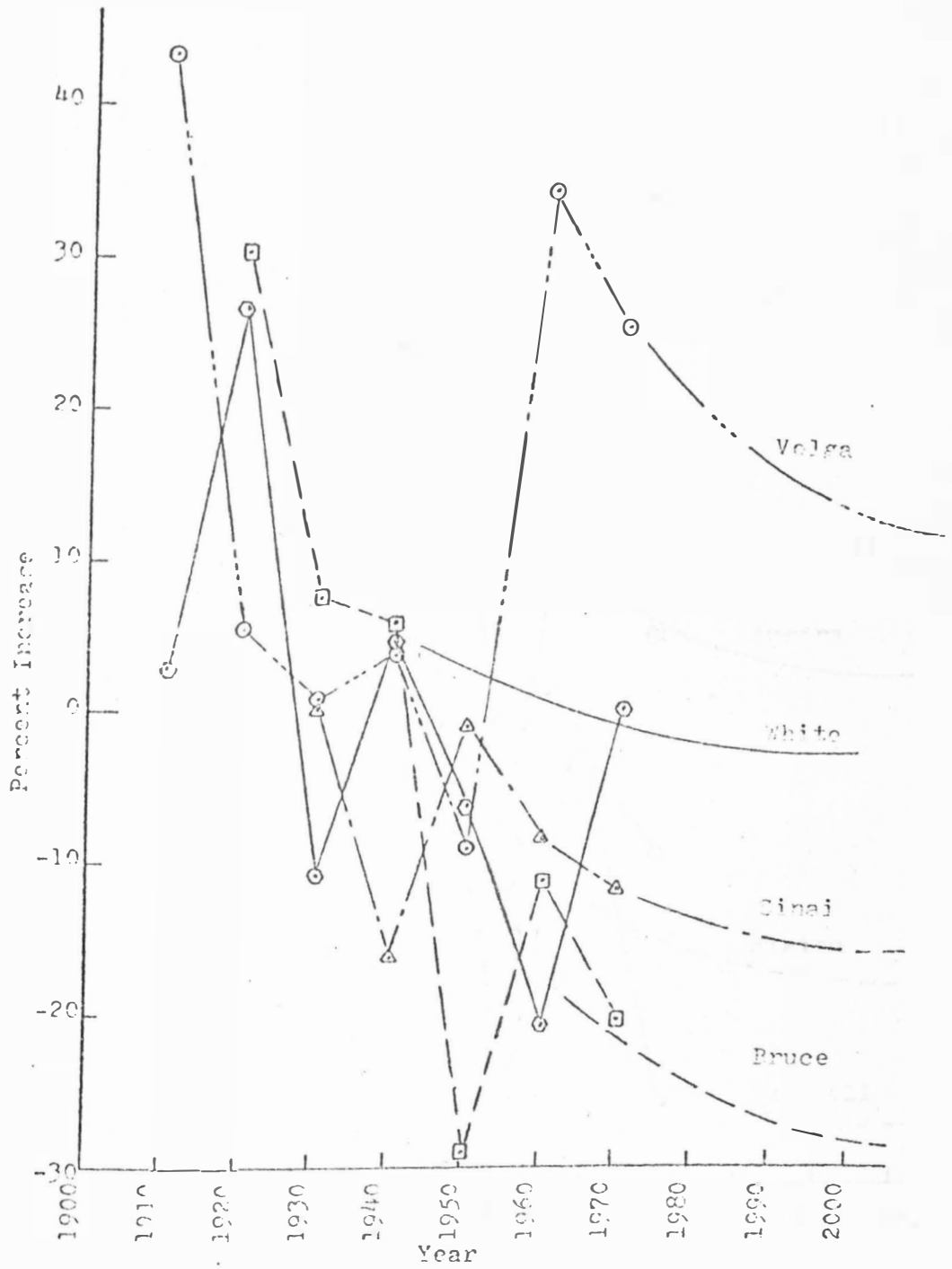

Figure a-3: Arithmetic Progression, Volga, White, Sinai, and Bruce.

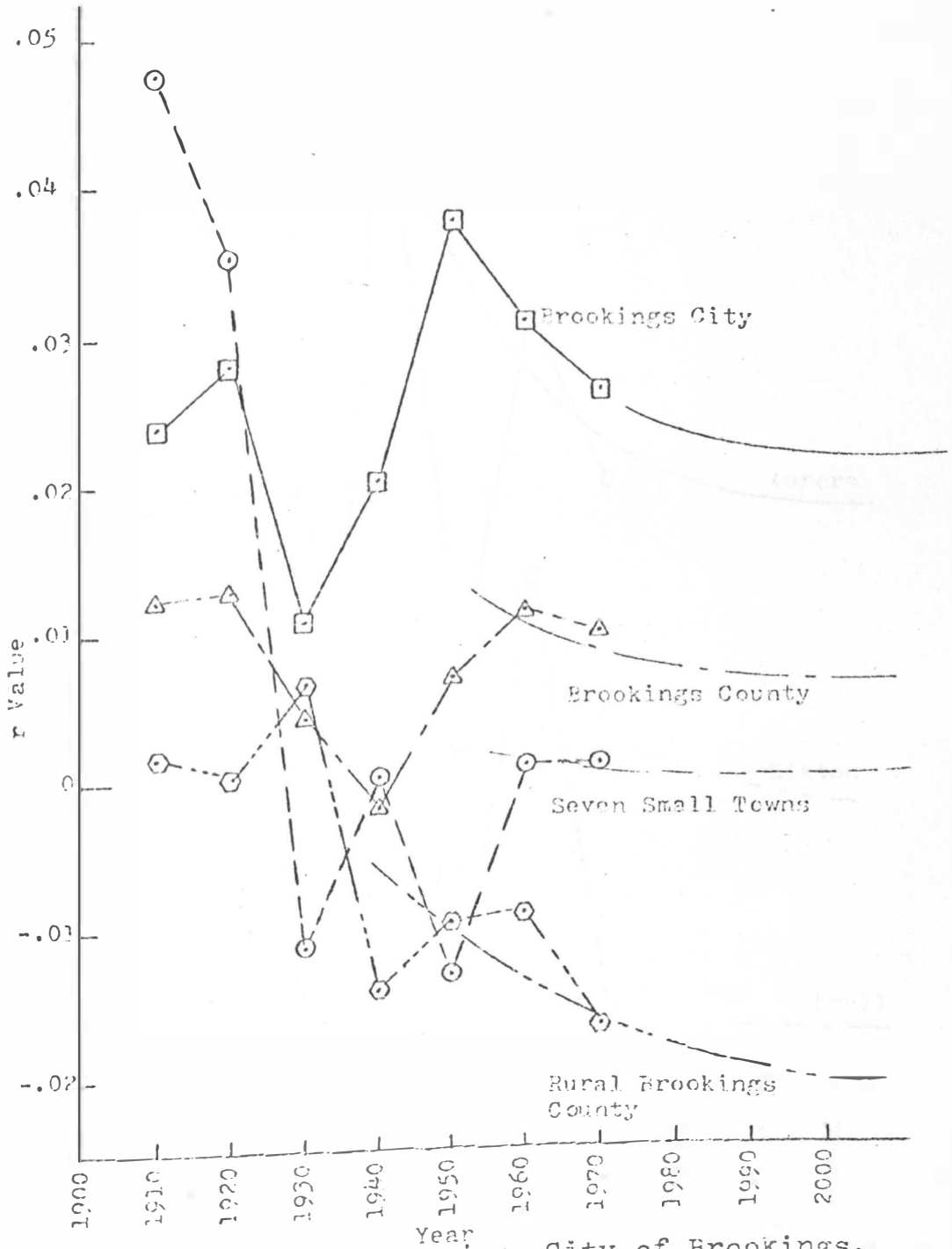

Figure A-5: Geometric Progression, City of Brookings, Brookings County, Seven Small Towns and Brookings County Rural.

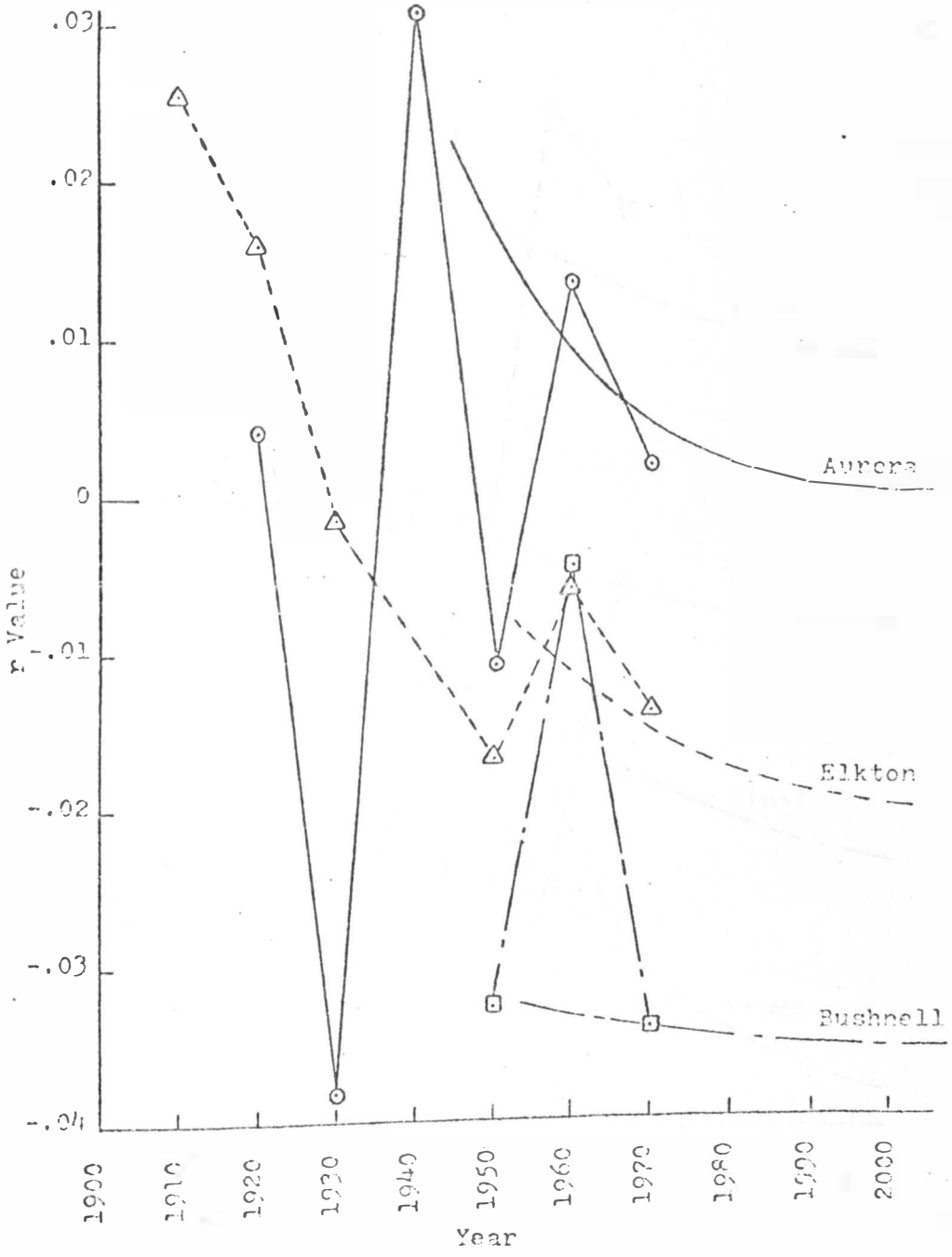

Figure A-6: Geometric Progression, Aurora, Elkton and Bushnell.

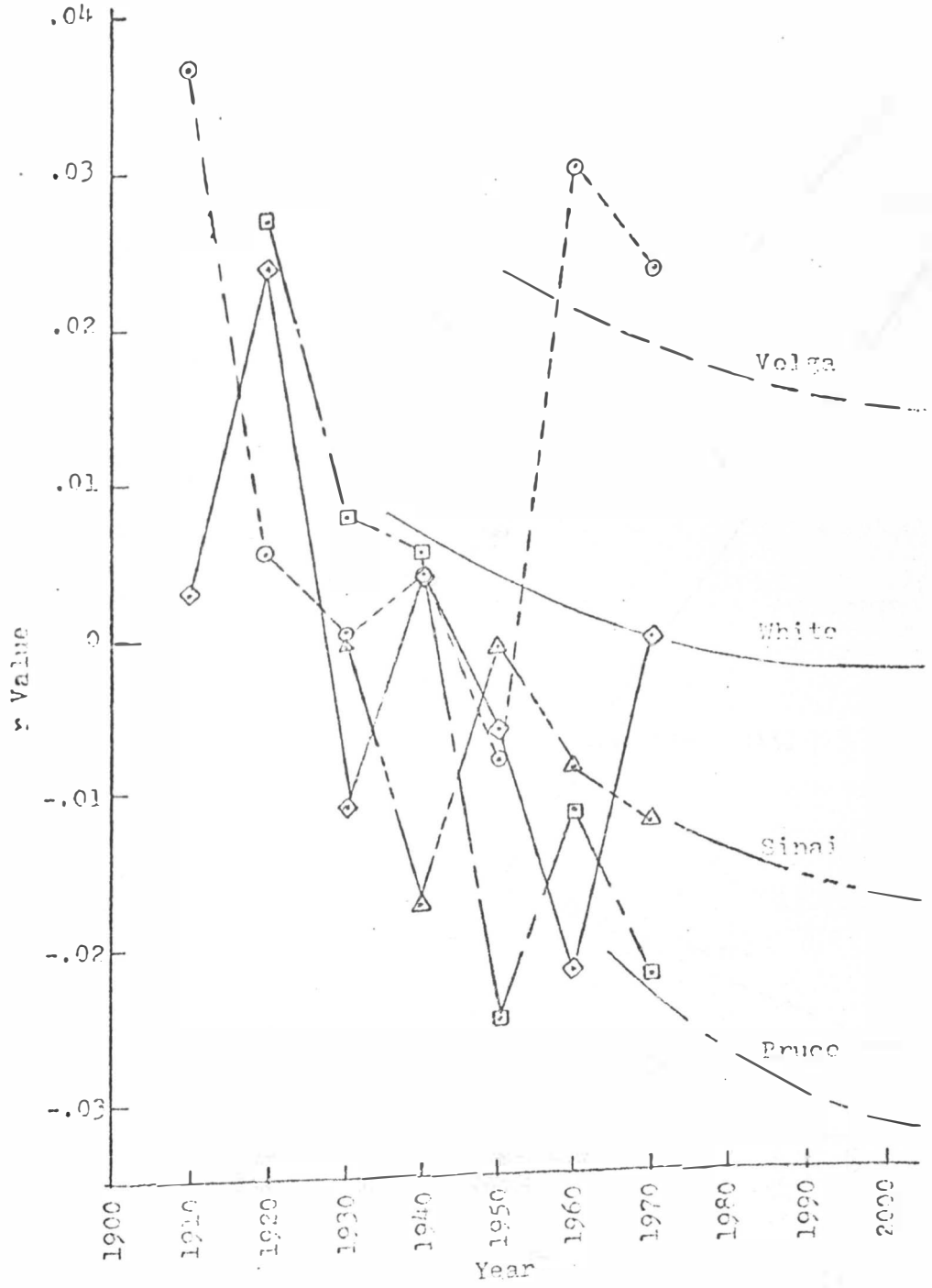

Figure A-7: Geometric Progression, Volga, White, Sinai, and Bruce.

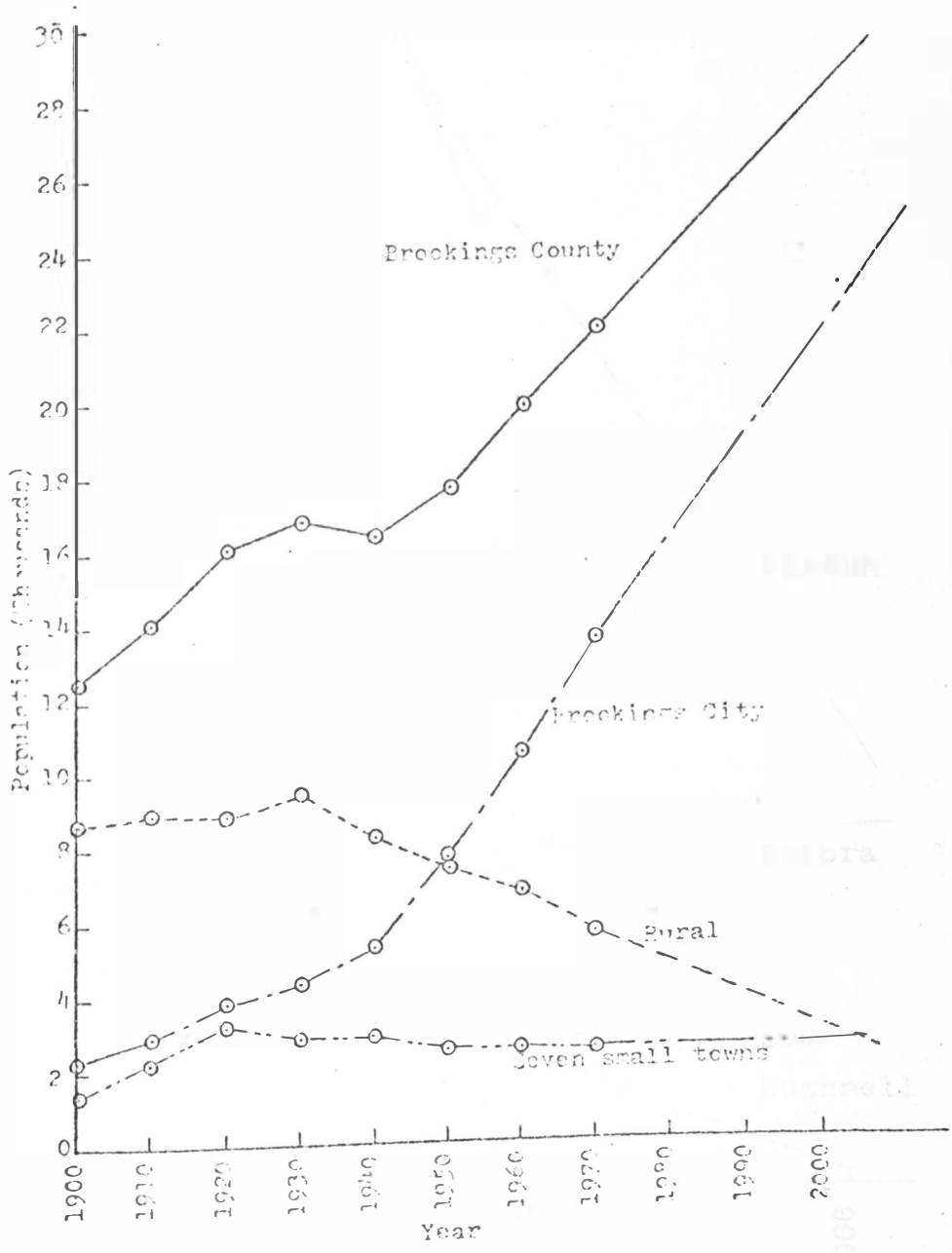

Figure A-8: Straight Line Projection, Brookings County, City of Brookings, Brookings County Rural and Seven Small Towns.

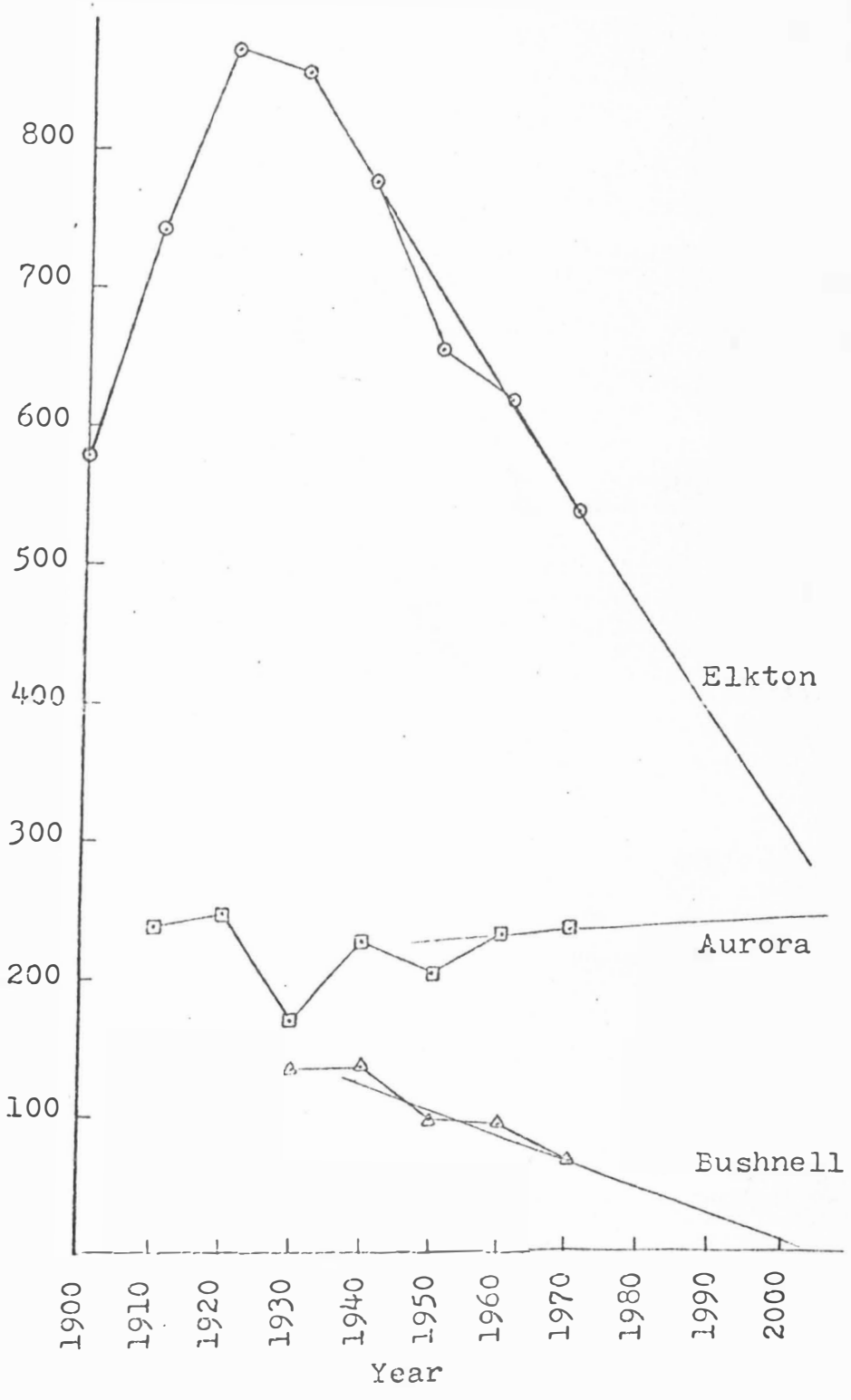

Figure A-9: Straight Line Projection, Elkton, Aurora And Bushnell

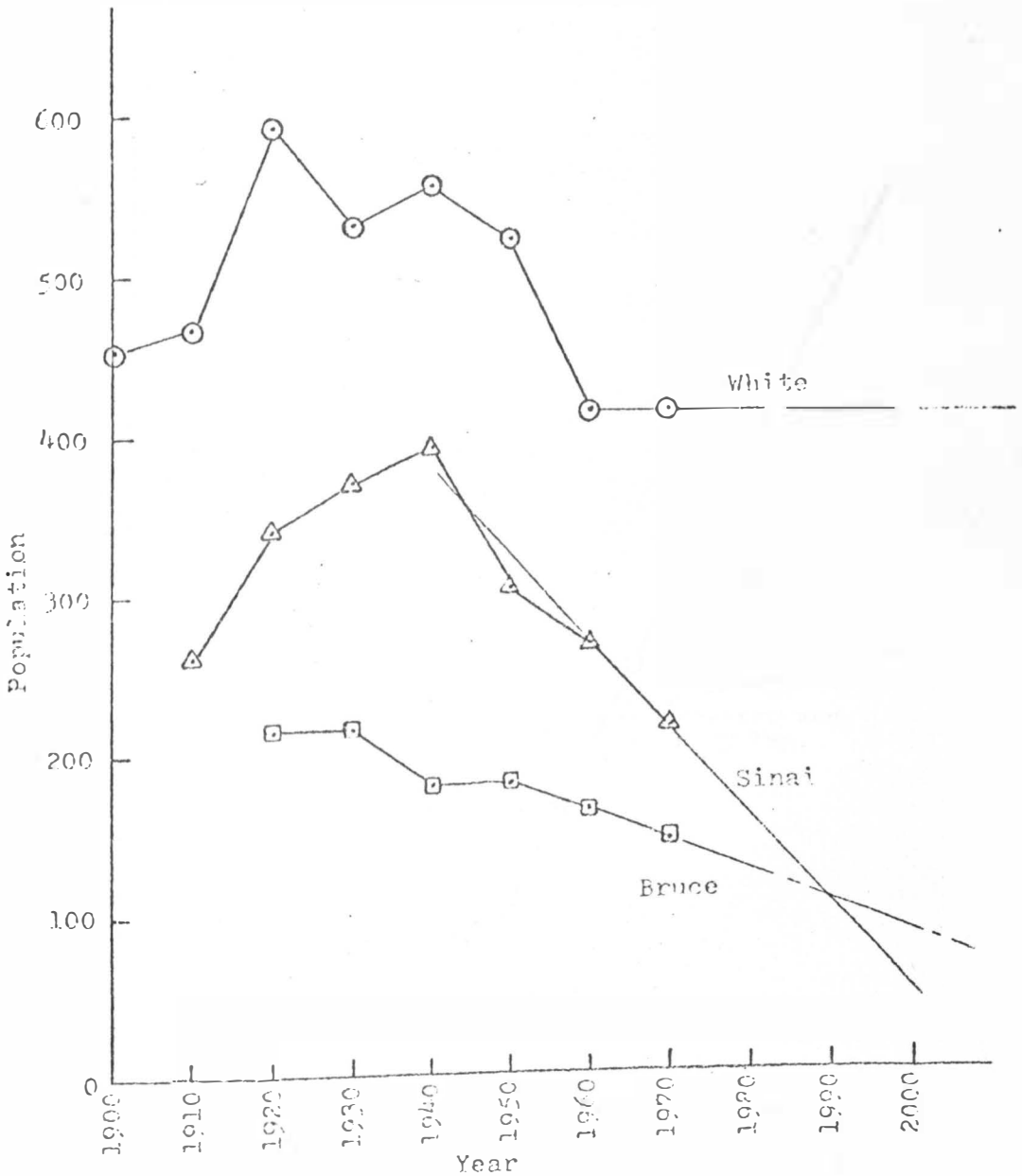

Figure A-10: Straight Line Projection, White, Sinai and Bruce.

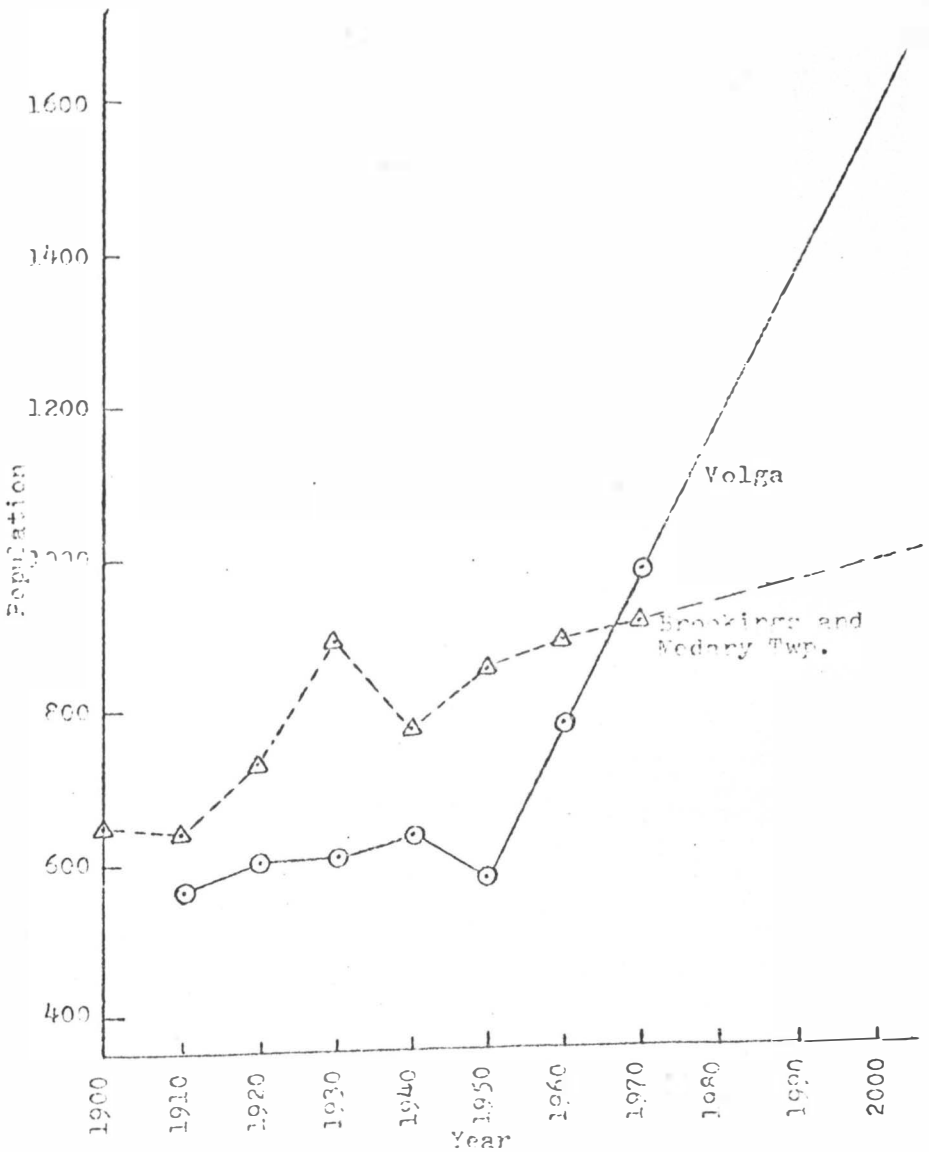

Figure A-11: Straight Line Projection, Volga, Brookings and Medary Township.

APPENDIX B

Estimated Quantities of Solid Waste for Brookings County, City of Brookings, seven small Towns and the Rural Townships for the Years of 1970, 1980, 1990 and 2000.

Table B-1: Quantities of Solid Waste Estimated for Brookings County, 1970.

	1970 Pop.	Pounds / Day	Pounds / Week	Loose Volume C.Y./ Week *	Compacted Volume C.Y./ Week **
Townships					
Afton	235	470	3,290	18.8	7.3
Alton	258	516	3,612	20.6	8.0
Argo	211	422	2,954	16.9	6.6
Aurora	290	580	4,060	23.2	9.0
Bangor	234	468	3,276	18.7	7.3
Brookings	398	796	5,572	31.8	12.4
Elkton	148	296	2,072	11.8	4.6
Eureka	215	430	3,010	17.2	6.7
Lake Hendricks	185	370	2,590	14.8	5.8
Laketon	203	406	2,842	16.2	6.3
Lake Sinai	226	452	3,164	18.1	7.0
Medary	508	1,016	7,112	40.6	15.8
Oak Lake	233	466	3,262	18.6	7.2
Oakwood	226	452	3,164	18.1	7.0
Oslo	260	520	3,640	20.8	8.1
Parnell	227	454	3,178	18.2	7.1
Preston	239	478	3,346	19.1	7.4
Richland	203	406	2,842	16.2	6.3
Sherman	178	356	2,492	14.2	5.5
Sterling	304	608	4,256	24.3	9.5
Trenton	273	546	3,822	21.8	8.5
Volga	324	648	4,536	25.9	10.1
Winsor	256	512	3,584	20.5	8.0
Total Rural	5,834	11,668	81,676	466.4	181.5
Towns					
Brookings	13,717	58,983	412,881	2,359.3	917.5
Aurora	237	1,019	7,133	41.0	15.9
Bushnell	65	280	1,960	11.2	4.4
Elkton	541	2,326	16,282	93.0	36.2
White	418	1,797	12,579	71.9	28.0
Bruce	217	933	6,531	37.3	14.5
Sinai	147	632	4,424	25.3	9.8
Volga	982	4,223	29,561	168.9	65.7
Total Towns	16,324	70,193	491,351	2,807.9	1,092.0
Total County	22,158	81,861	573,027	3,274.3	1,273.5

* 175 Pounds per Cubic Yard Loose Weight
** 450 Pounds per Cubic Yard Compacted Weight

Table B-2: Quantities of Solid Waste Estimated for Brookings County, 1980.

	1980 Pop.	Pounds / Day	Pounds / Week	Loose Volume C.Y./ Week *	Compacted Volume C.Y./ Week **
Townships					
Afton	187	468	3,276	18.7	7.3
Alton	207	518	3,626	20.7	8.1
Argo	169	423	2,961	16.9	6.6
Aurora	233	583	4,081	23.3	9.1
Bangor	188	470	3,290	18.8	7.3
Brookings	411	1,028	7,196	41.1	16.0
Elkton	119	298	2,086	11.9	4.6
Eureka	173	433	3,031	17.3	6.7
Lake Hendricks	149	373	2,611	14.9	5.8
Laketon	163	408	2,856	16.3	6.3
Lake Sinai	181	453	3,171	18.1	7.0
Medary	524	1,310	9,170	52.4	20.4
Oak Lake	187	468	3,276	18.7	7.3
Oakwood	181	453	3,171	18.1	7.0
Oslo	209	523	3,661	20.9	8.1
Parnell	182	455	3,185	18.2	7.1
Preston	192	480	3,360	19.2	7.5
Richland	163	408	2,856	16.3	6.3
Sherman	143	358	2,506	14.3	5.6
Sterling	244	610	4,270	24.4	9.5
Trenton	219	548	3,836	21.9	8.5
Volga	260	650	4,550	26.0	10.1
Winsor	206	515	3,605	20.6	8.0
Total Rural	4,890	12,233	85,631	489.0	190.2
Towns					
Brookings	17,235	88,933	622,531	3,557.6	1,383.4
Aurora	239	1,233	8,631	49.3	19.2
Bushnell	46	237	1,659	9.5	3.7
Elkton	448	2,312	16,184	92.5	36.0
White	414	2,136	14,952	85.4	33.2
Bruce	162	836	5,852	33.4	13.0
Sinai	127	655	4,585	26.1	10.2
Volga	1,176	6,068	42,476	242.7	94.4
Total Towns	19,847	102,410	716,870	4,096.3	1,593.1
Total County	24,737	114,643	802,501	4,885.3	1,783.3

* 175 Pounds per Cubic Yard Loose Weight
** 450 Pounds per Cubic Yard Compacted Weight

Table B-3: Quantities of Solid Waste Estimated for Brookings County, 1990.

	1990 Pop.	Pounds / Day	Pounds / Week	Loose Volume C.Y./ Week *	Compacted Volume C.Y./ Week **
Townships					
Afton	145	452	3,164	18.1	7.0
Alton	160	499	3,493	20.0	7.8
Argo	131	409	2,863	16.4	6.4
Aurora	180	562	3,934	22.5	8.7
Bangor	146	456	3,192	18.2	7.1
Brookings	424	1,323	9,261	52.9	20.6
Elkton	92	287	2,009	11.5	4.5
Eureka	134	418	2,926	16.7	6.5
Lake Hendricks	115	359	2,513	14.4	5.6
Laketon	126	393	2,751	15.7	6.1
Lake Sinai	140	437	3,059	17.5	6.8
Medary	541	1,688	11,816	67.5	26.3
Oak Lake	145	452	3,164	18.1	7.0
Oakwood	140	437	3,059	17.5	6.8
Oslo	162	505	3,535	20.2	7.9
Parnell	141	440	3,080	17.6	6.8
Preston	149	465	3,255	18.6	7.2
Richland	126	393	2,751	15.7	6.1
Sherman	111	346	2,422	13.8	5.4
Sterling	189	590	4,130	23.6	9.2
Trenton	170	530	3,710	21.2	8.2
Volga	201	627	4,389	25.1	9.8
Winsor	160	499	3,493	20.0	7.8
Total Rural	4,028	12,567	87,969	502.8	195.6
Towns					
Brookings	20,984	129,891	909,237	5,195.6	2,020.5
Aurora	241	1,492	10,444	59.7	23.2
Bushnell	30	186	1,302	7.4	2.9
Elkton	364	2,253	15,771	90.1	35.0
White	409	2,532	17,724	101.3	39.4
Bruce	115	712	4,984	28.5	11.1
Sinai	108	669	4,683	26.8	10.4
Volga	1,372	8,493	59,451	339.7	132.1
Total Town	23,623	146,228	1023,596	5,849.1	2,274.6
Total County	27,651	158,795	1111,565	6,451.9	2,470.2

* 175 Pounds per Cubic Yard Loose Weight
** 450 Pounds per Cubic Yard Compacted Weight

Table B-4: Quantities of Solid Waste Estimated for Brookings County, 2000.

	2000 Pop.	Pounds / Day	Pounds / Week	Loose Volume C.Y./ Week *	Compacted Volume C.Y./ Week **
Townships					
Afton	109	425	2,975	17.0	6.6
Alton	121	472	3,304	18.9	7.3
Argo	99	386	2,702	15.4	6.0
Aurora	136	530	3,710	21.2	8.2
Bangor	110	429	3,003	17.2	6.7
Brookings	436	1,700	11,900	68.0	26.4
Elkton	69	269	1,883	10.8	4.2
Eureka	101	394	2,758	15.8	6.1
Lake Hendricks	87	339	2,373	13.6	5.3
Laketon	95	371	2,597	14.8	5.8
Lake Sinai	106	413	2,891	16.5	6.4
Medary	554	2,161	15,127	86.4	33.6
Oak Lake	109	425	2,975	17.0	6.6
Oakwood	106	413	2,891	16.5	6.4
Oslo	122	476	3,332	19.0	7.4
Parnell	106	413	2,891	16.5	6.4
Preston	112	437	3,059	17.5	6.8
Richland	95	371	2,597	14.8	5.8
Sherman	84	328	2,296	13.1	5.1
Sterling	143	558	3,906	22.3	8.7
Trenton	128	499	3,493	20.0	7.8
Volga	152	593	4,151	23.7	9.2
Winsor	121	472	3,304	18.9	7.3
Total Rural	3,301	12,874	90,118	514.9	200.1
Towns					
Brookings	25,293	187,927	1315,489	7,517.1	2,923.3
Aurora	245	1,820	12,740	72.8	28.3
Bushnell	19	141	987	5.6	2.2
Elkton	291	2,162	15,134	86.5	33.6
White	403	2,994	20,958	119.8	46.6
Bruce	74	550	3,850	22.0	8.6
Sinai	91	676	4,732	27.0	10.5
Volga	1,574	11,695	81,865	467.8	181.9
Total Town	27,988	207,965	1455,755	8,318.6	3,235.0
Total County	31,289	220,839	1545,873	8,833.5	3,435.1

* 175 Pounds per Cubic Yard Loose Weight
** 450 Pounds per Cubic Yard Compacted Weight

Table B-5: Number of Containers Required for Temporary Residents of Brookings County, 1970 to 2000.

Area	Loose Volume C.Y./Week	Number Of Containers 3 C.Y. Size	4 C.Y. Size	6 C.Y. Size
1970				
Lake Poinsett	23.0	7.5	6.0	4.0
Oakwood Lakes	10.4	3.5	2.5	1.5
Lake Campbell	20.2	6.5	5.0	3.5
Total	53.6	17.5	13.5	9.0
1980				
Lake Poinsett	31.6	10.5	8.0	5.5
Oakwood Lakes	14.3	5.0	3.5	2.5
Lake Campbell	27.7	9.0	7.0	4.5
Total	73.6	24.5	18.5	12.5
1990				
Lake Poinsett	43.3	14.5	11.0	7.0
Oakwood Lakes	19.6	6.5	5.0	3.5
Lake Campbell	38.1	12.5	9.5	6.5
Total	101.0	33.5	25.5	17.0
2000				
Lake Poinsett	59.6	20.0	15.0	10.0
Oakwood Lakes	27.0	9.0	7.0	4.5
Lake Campbell	52.3	17.5	13.0	8.5
Total	138.9	46.5	35.0	23.0

APPENDIX C

Maps of the twenty three townships of rural Brookings County showing the proposed location of solid waste collection sites.

● Four-Cubic Yard Container Sites

◆ Six-Cubic Yard Container Sites

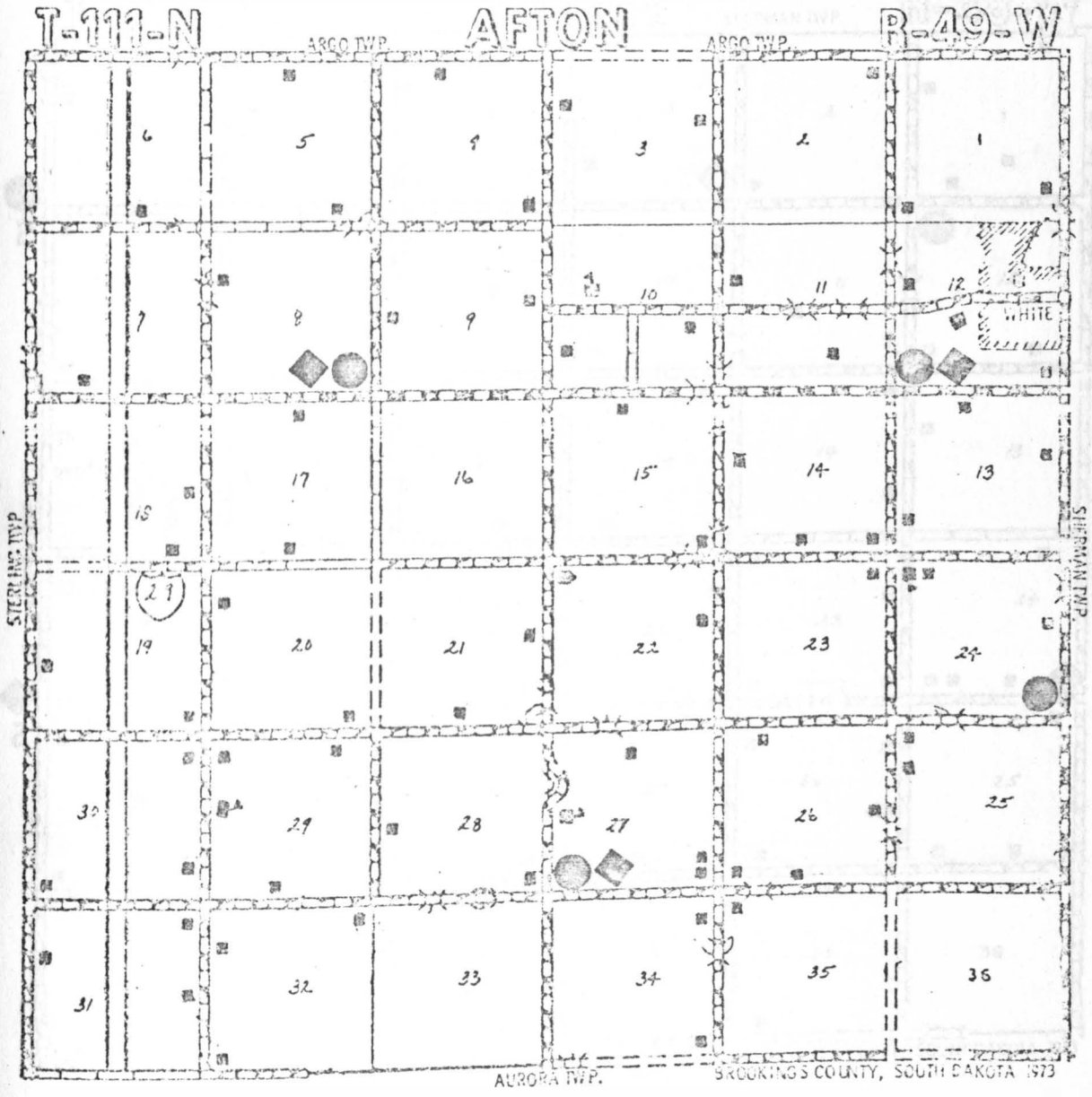

Figure C-1: Container Site Locations, Afton Township.

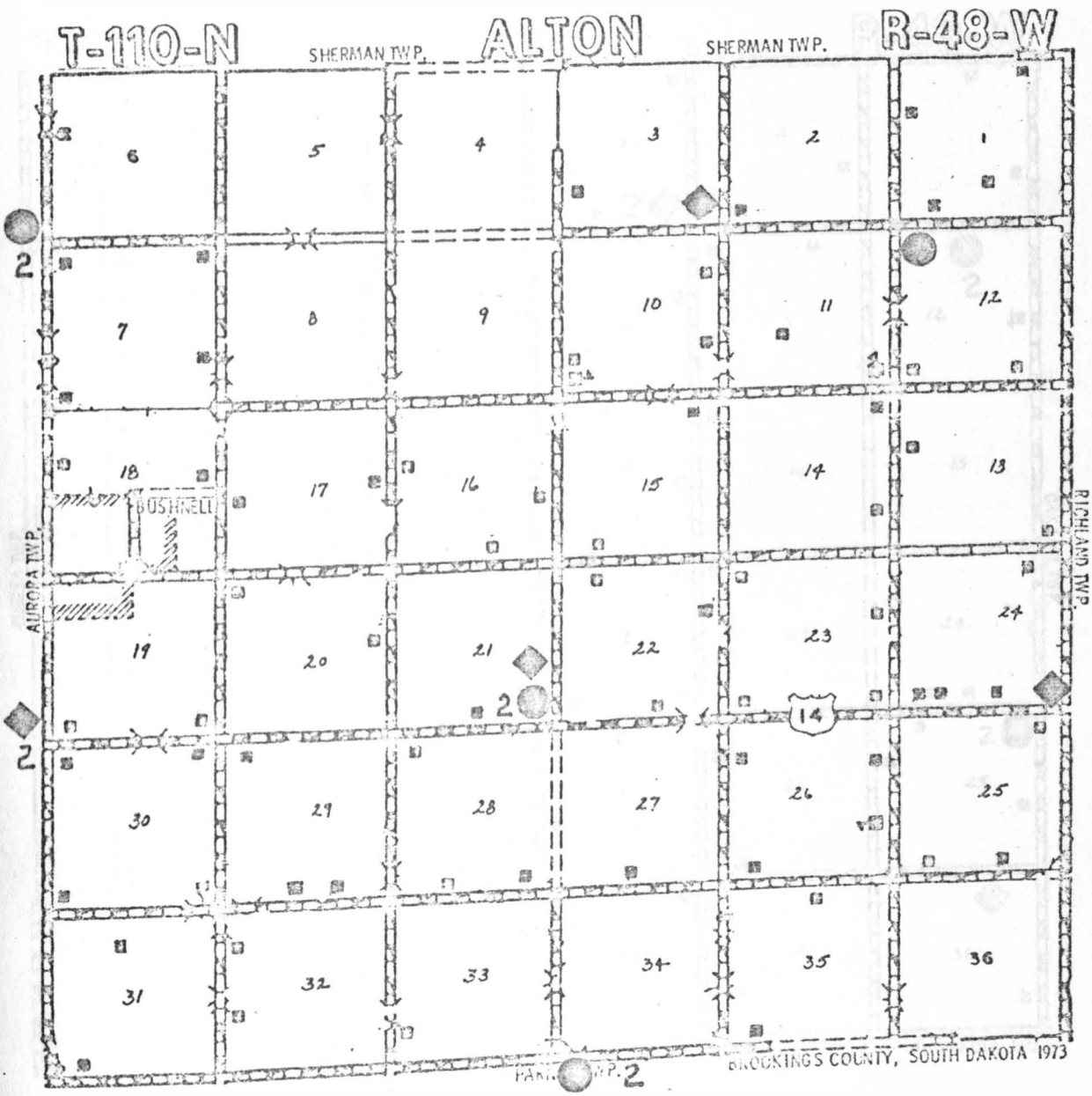

Figure C-2: Container Site Locations, Alton Township.

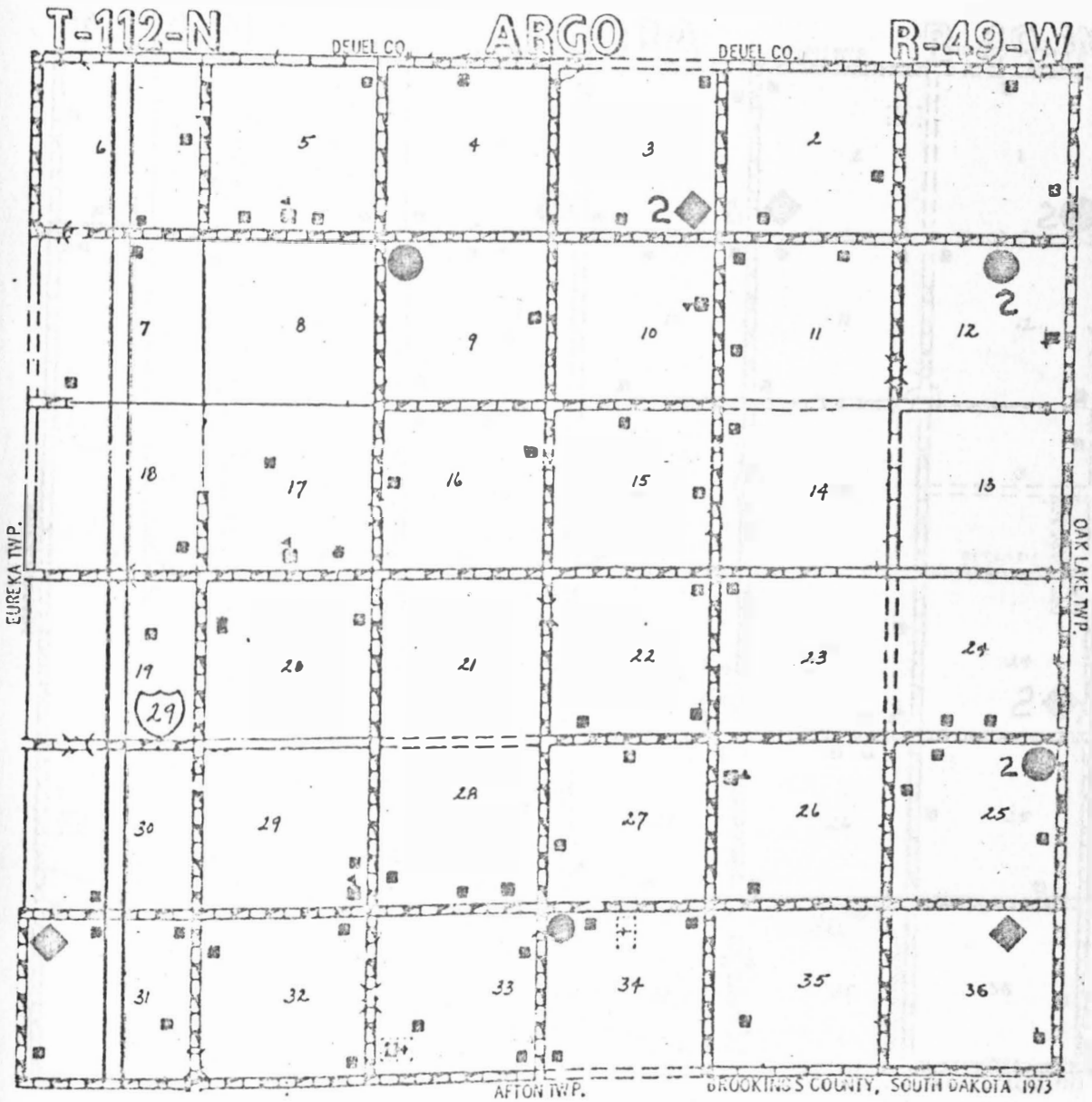

Figure C-3: Container Site Locations, Argo Township.

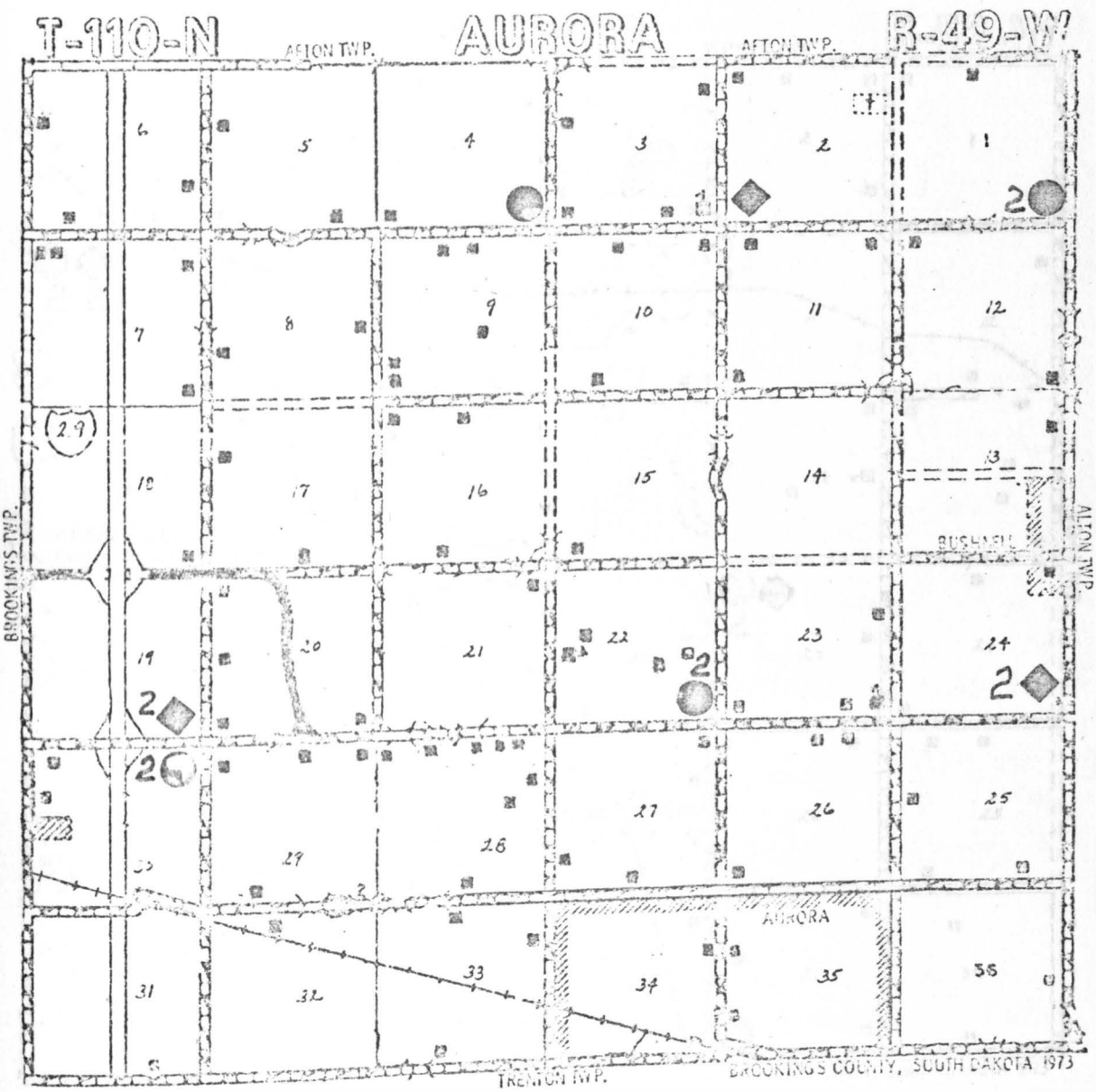

Figure C-4: Container Site Locations, Aurora Township.

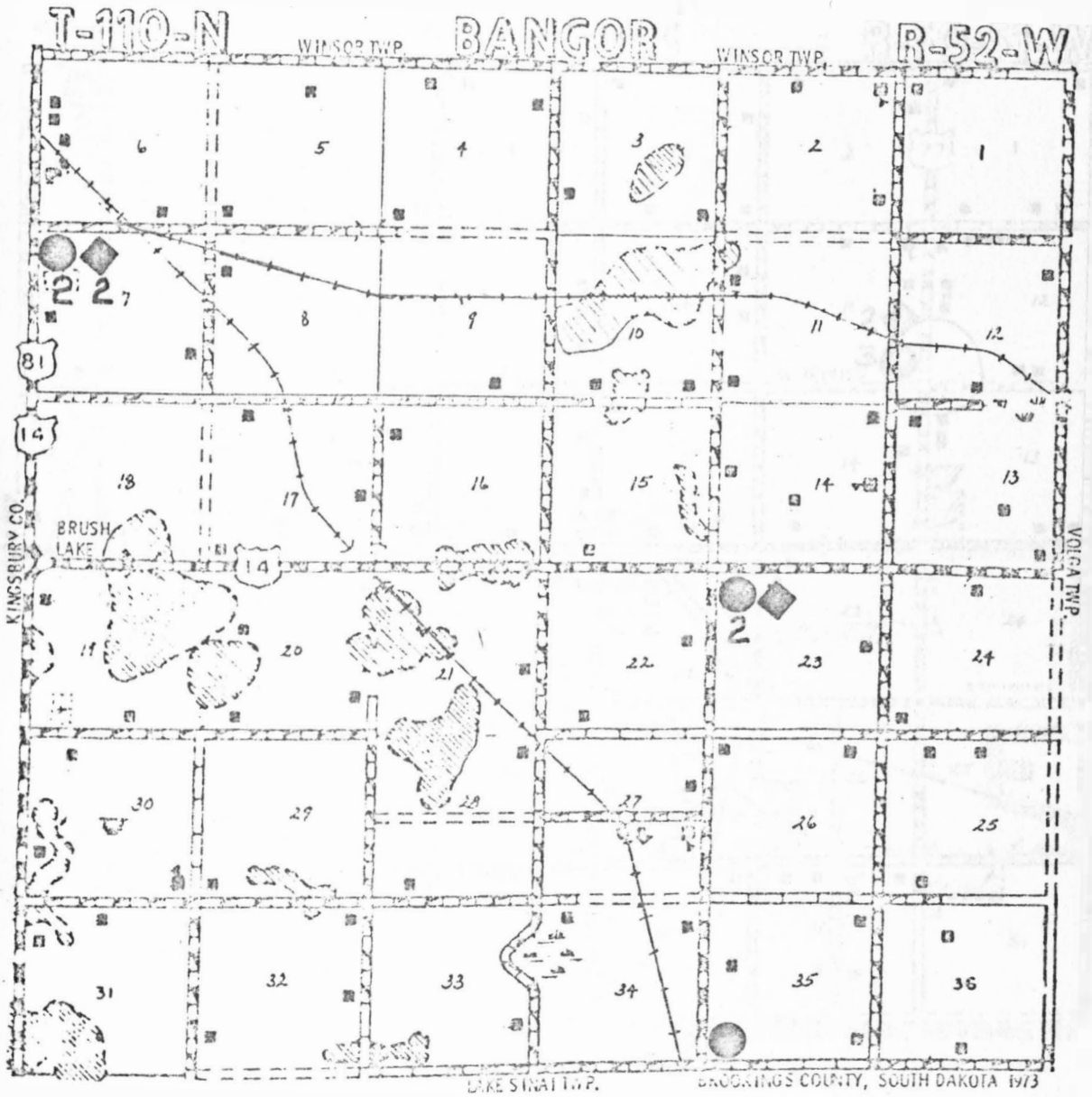

Figure C-5: Container Site Locations, Bangor Township.

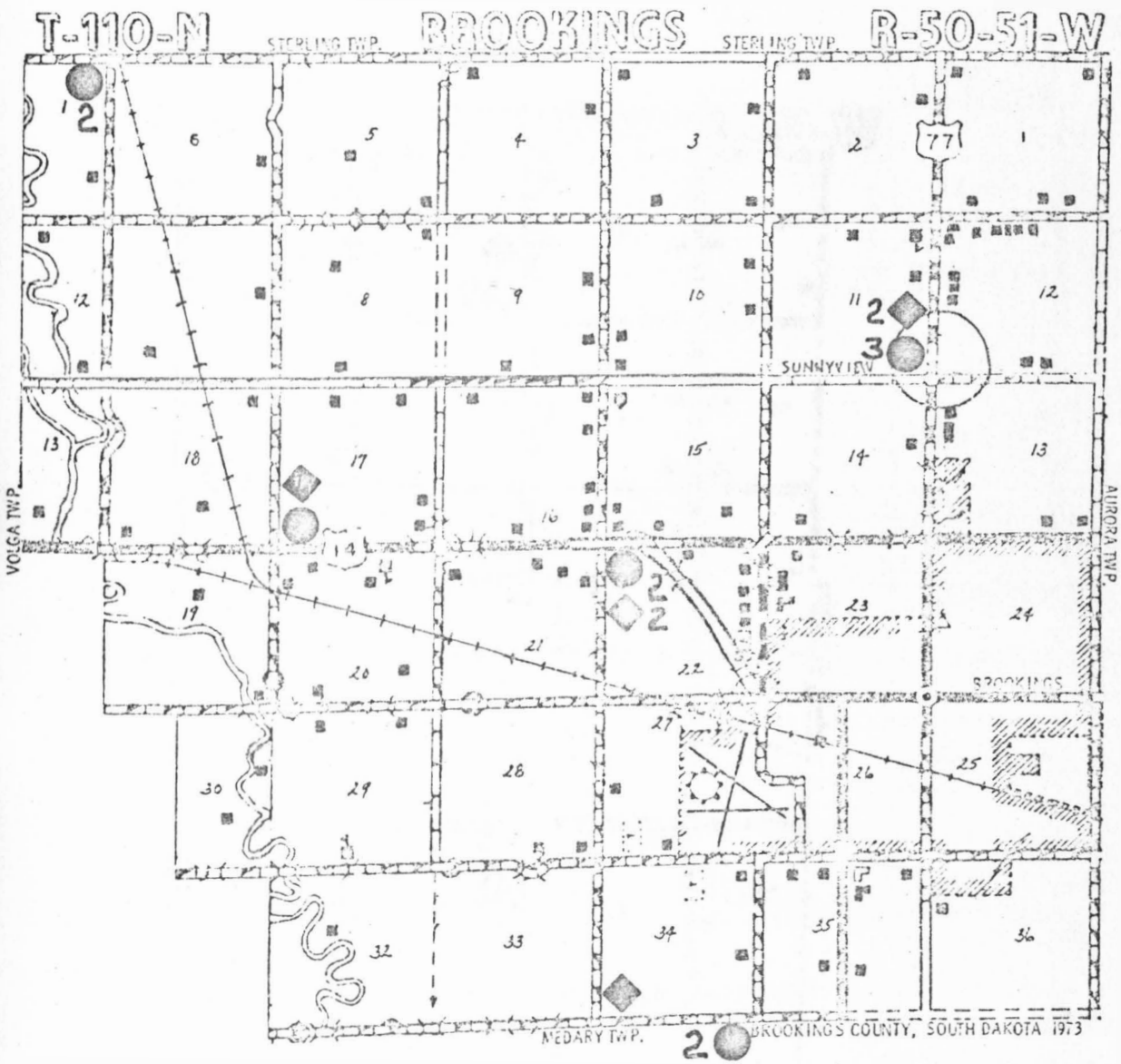

Figure C-6: Container Site Locations, Brookings Township.

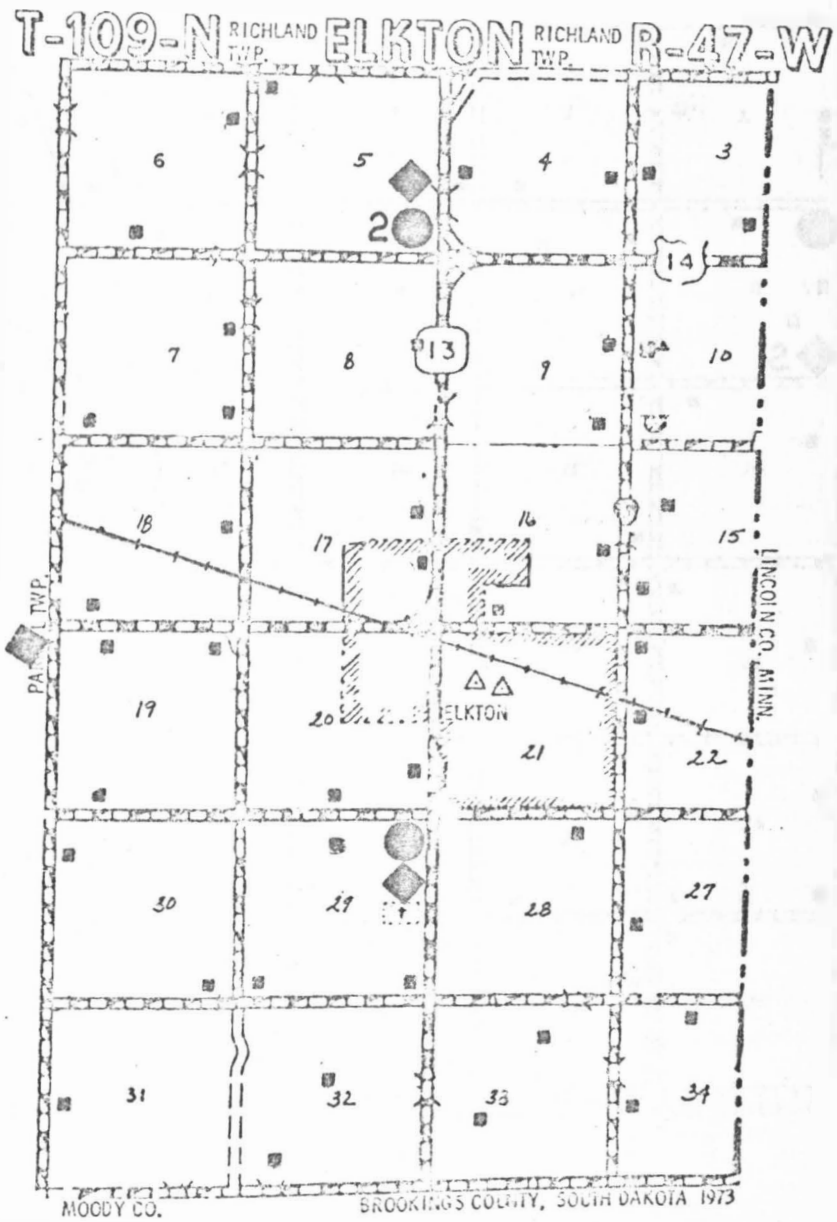

Figure C-7: Container Site Locations, Elkton Township.

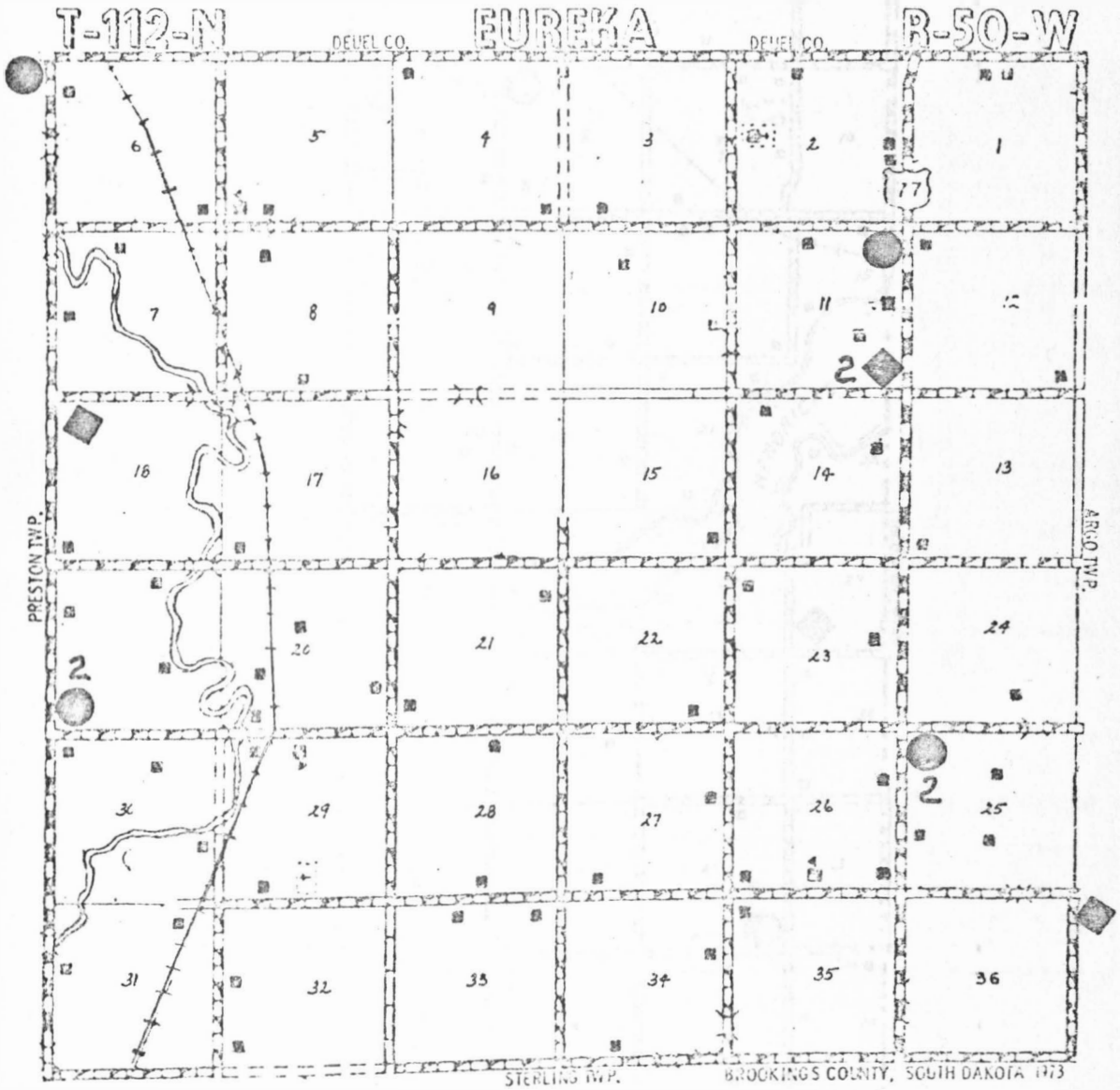

Figure C-8: Container Site Locations, Eureka Township.

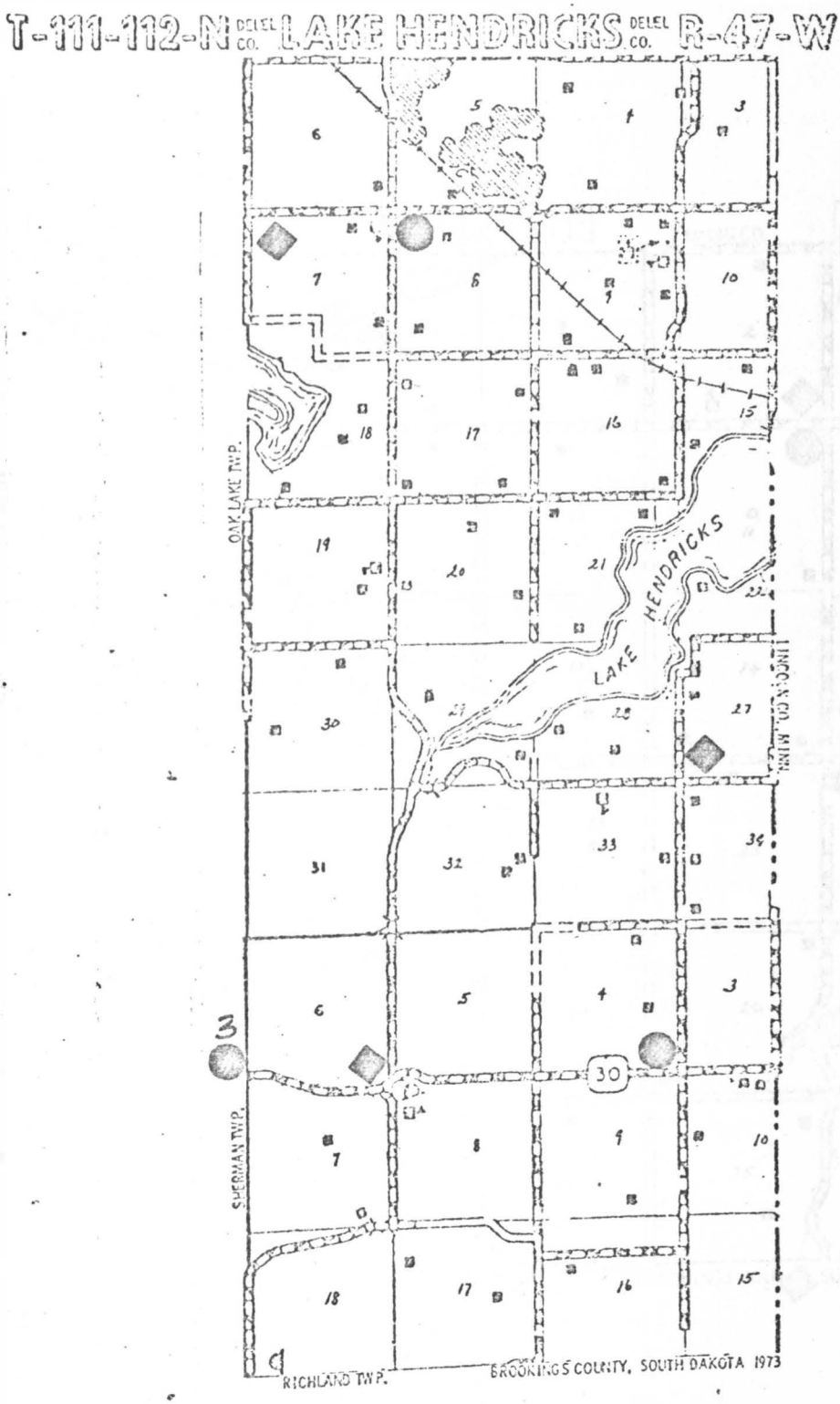

Figure C-9: Container Site Locations, Lake Hendricks Township.

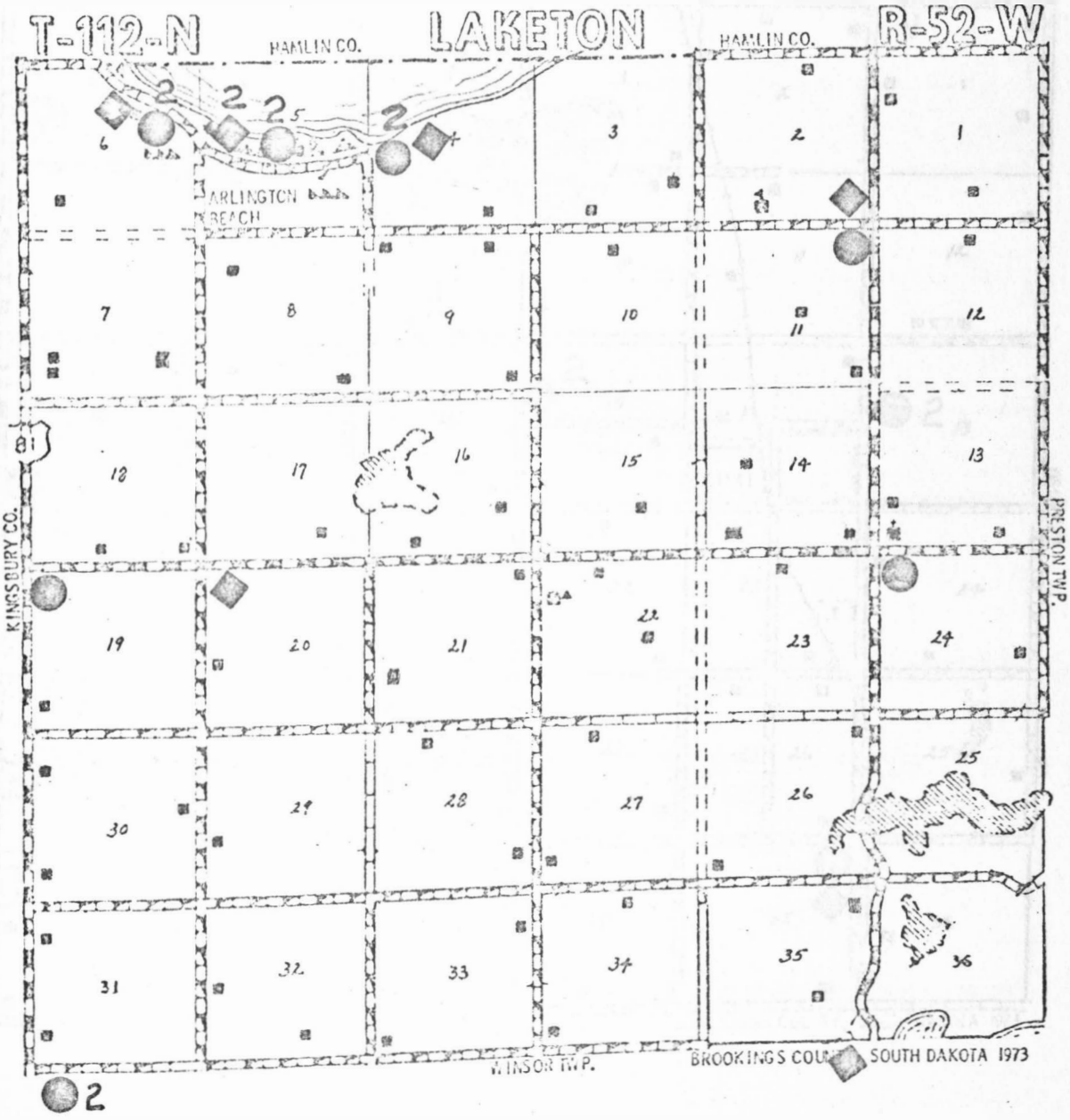

Figure C-10: Container Site Locations, Laketon Township.

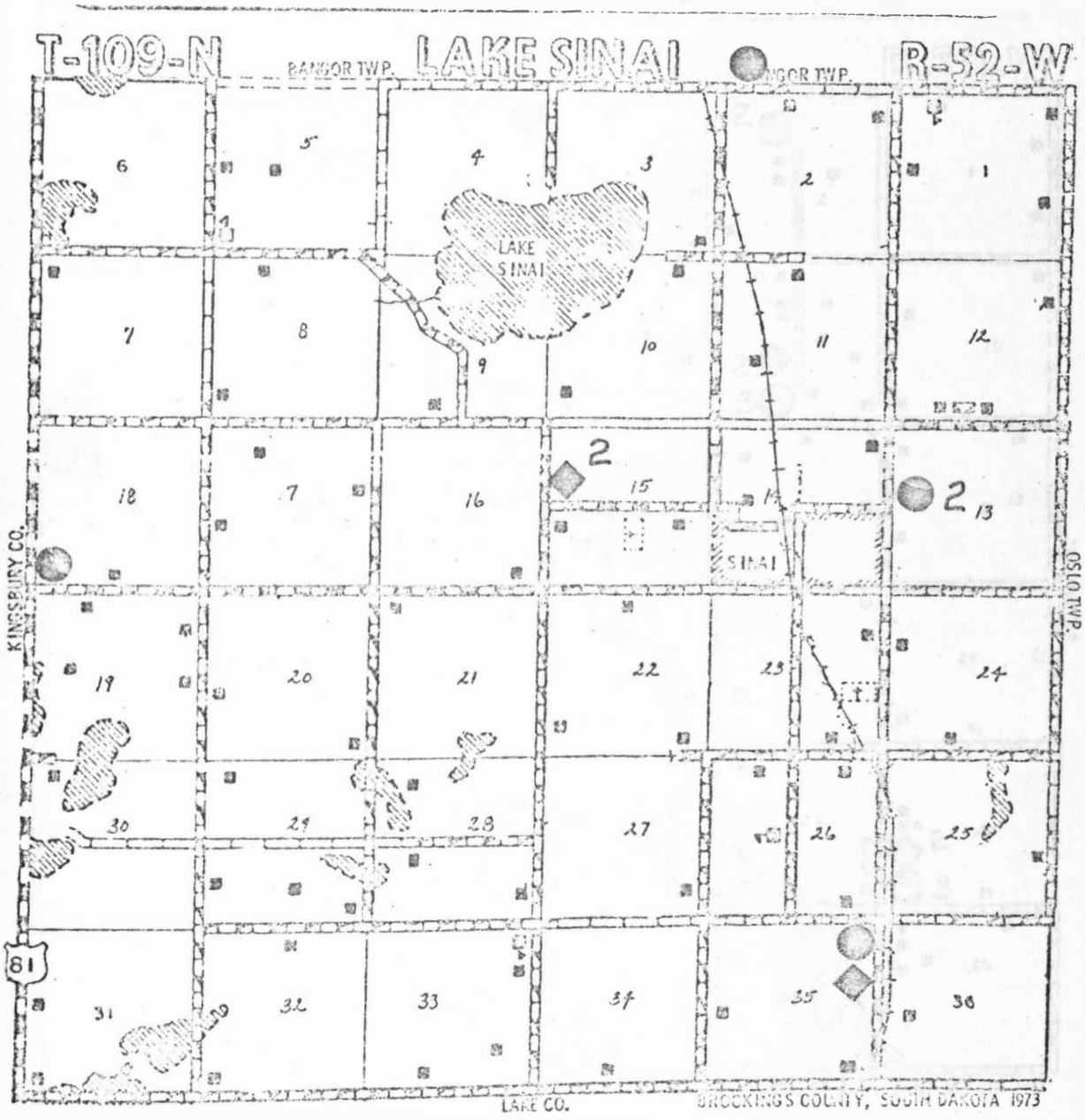

Figure C-11: Container Site Locations, Lake Sinai Township.

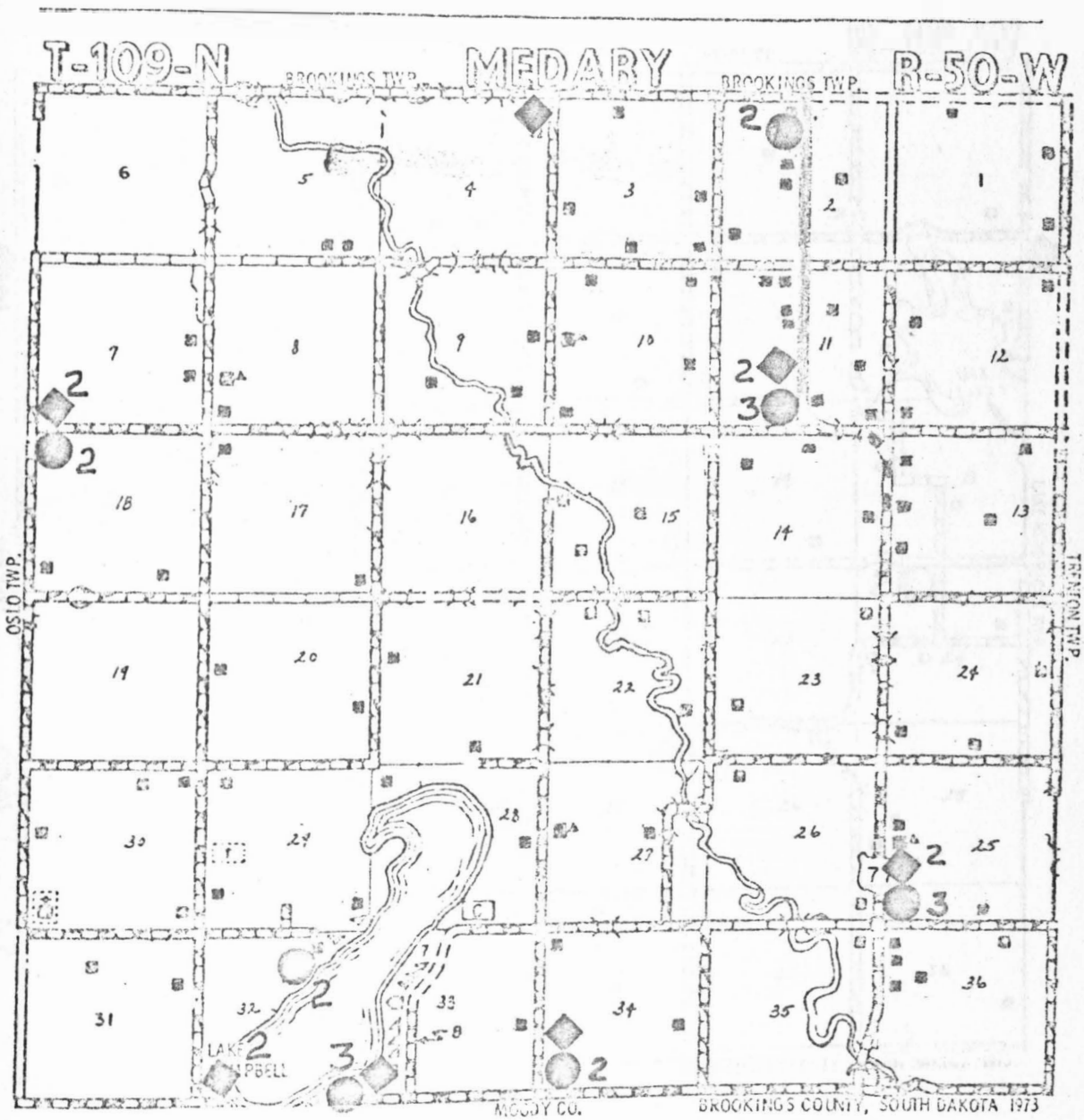

Figure C-12: Container Site Locations, Medary Township.

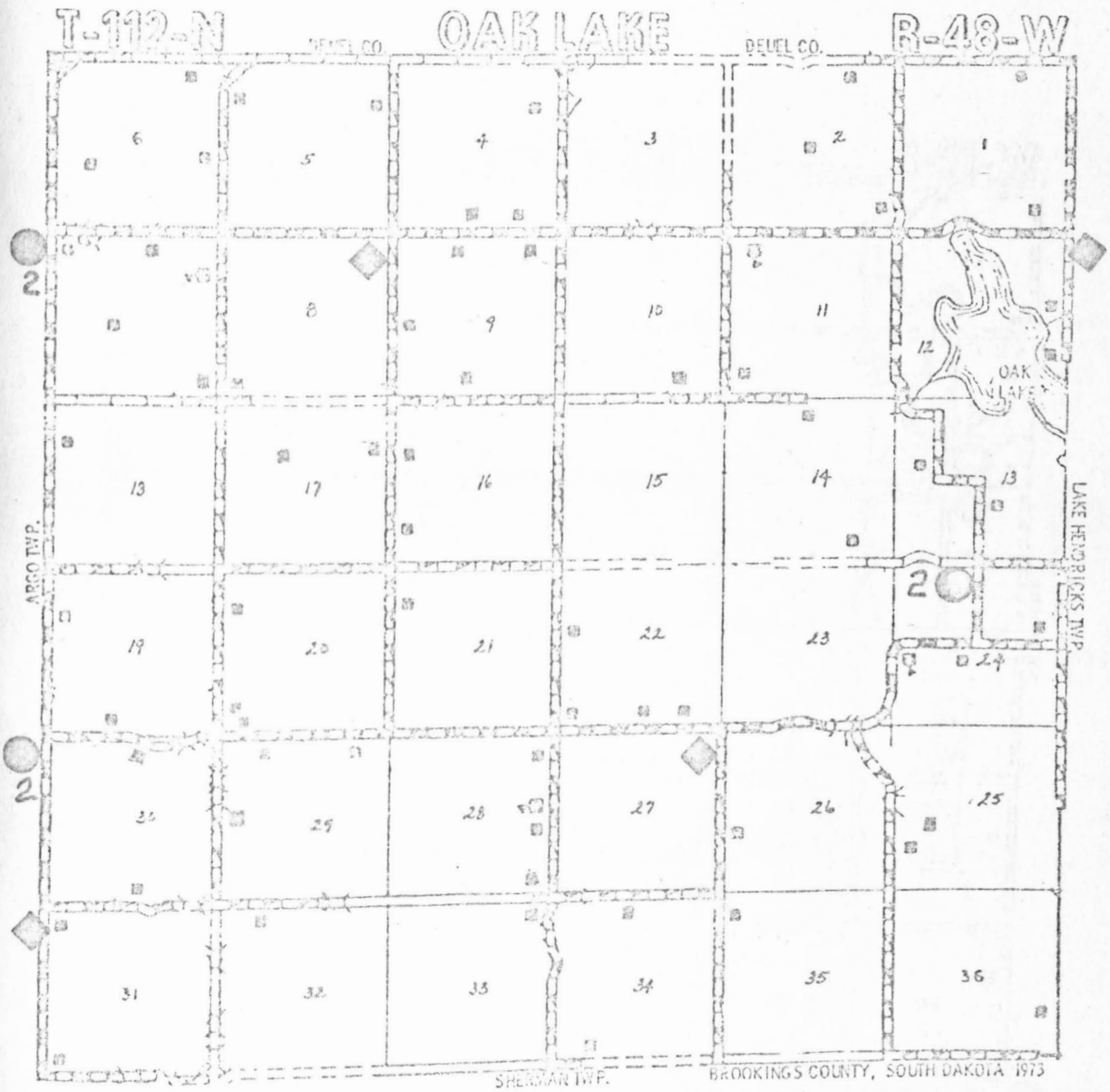

Figure C-13: Container Site Locations, Oak Lake Township.

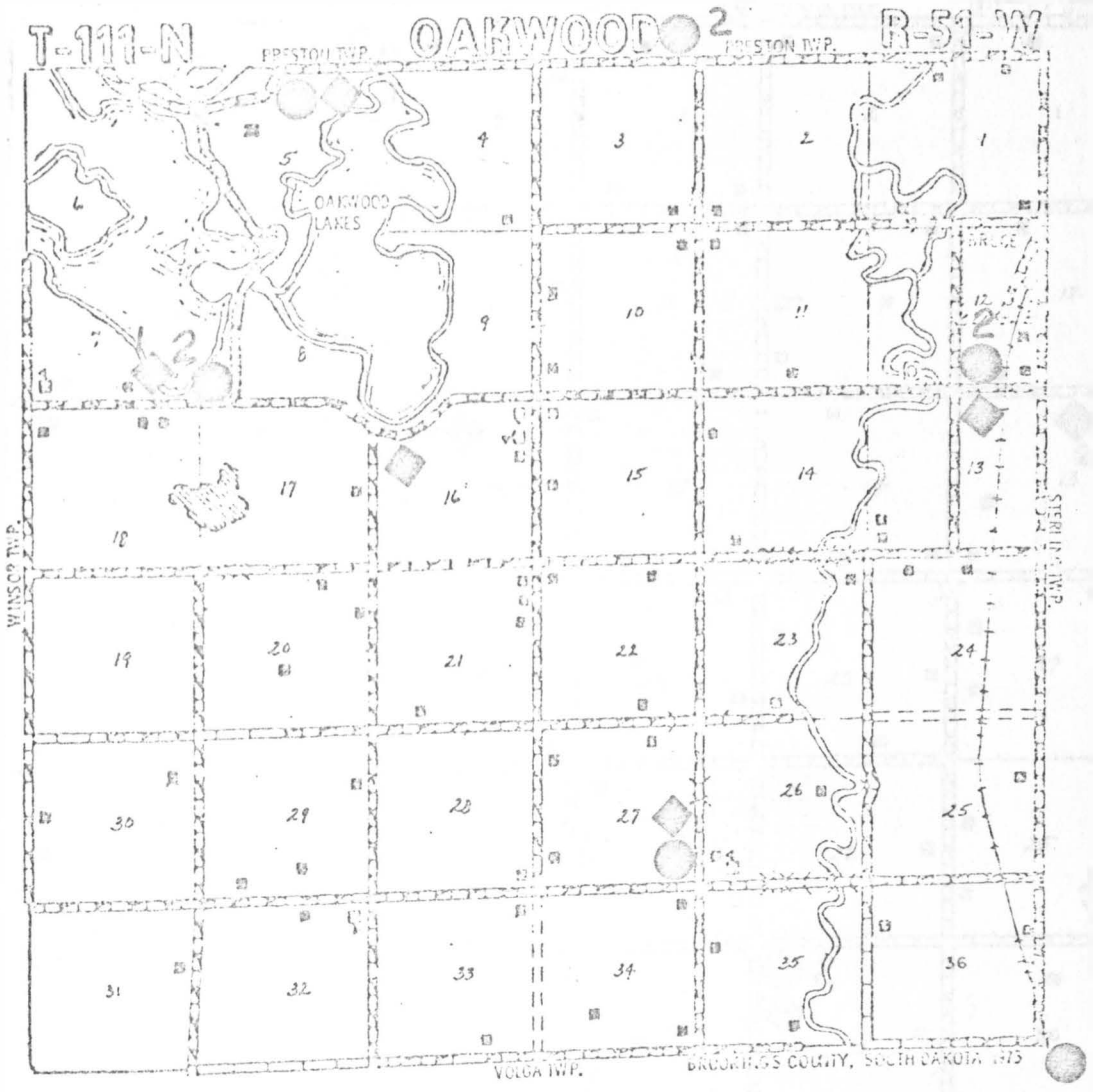

Figure C-14: Container Site Locations, Oakwood Township.

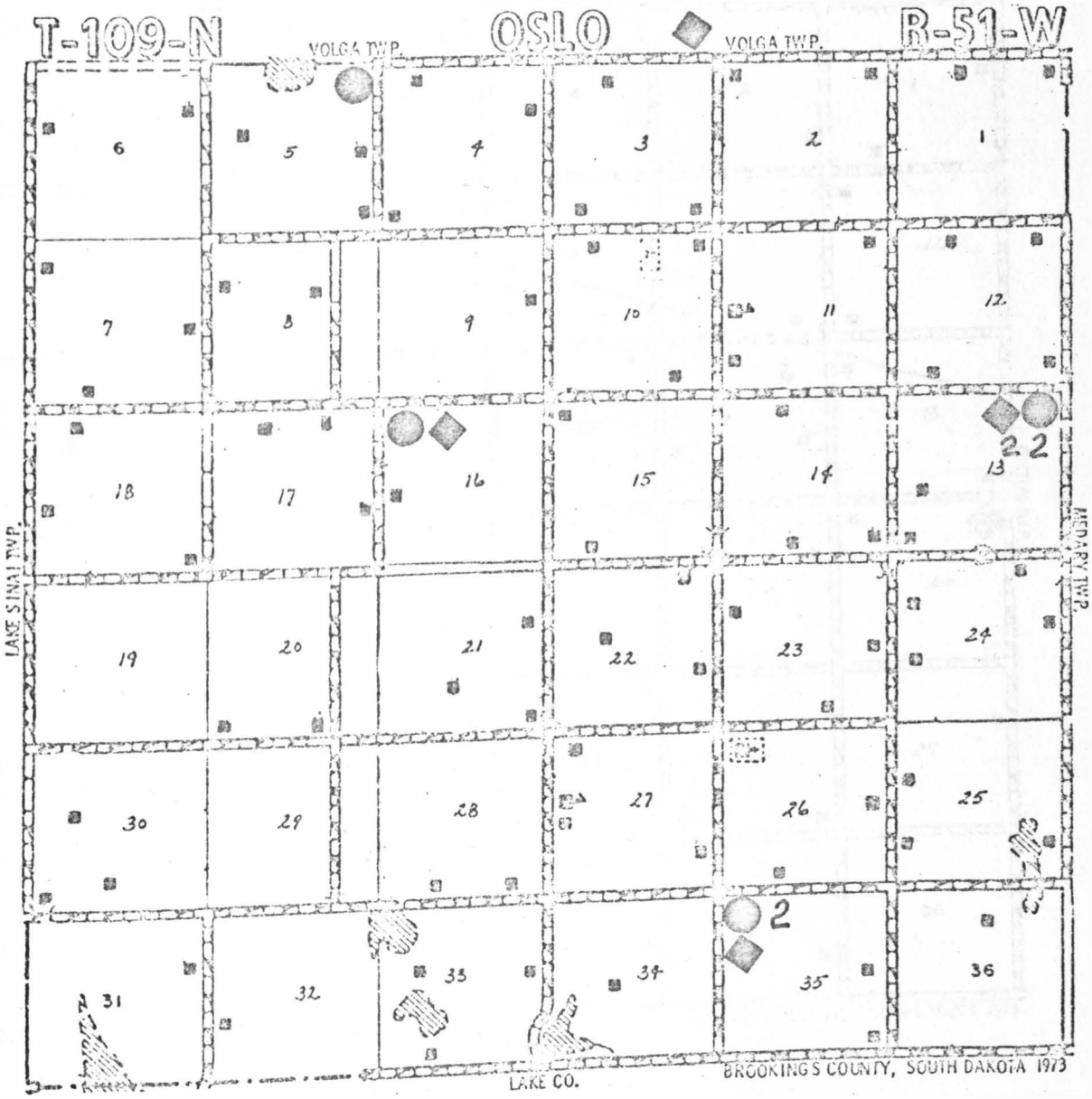

Figure C-15: Container Site Locations, Oslo Township.

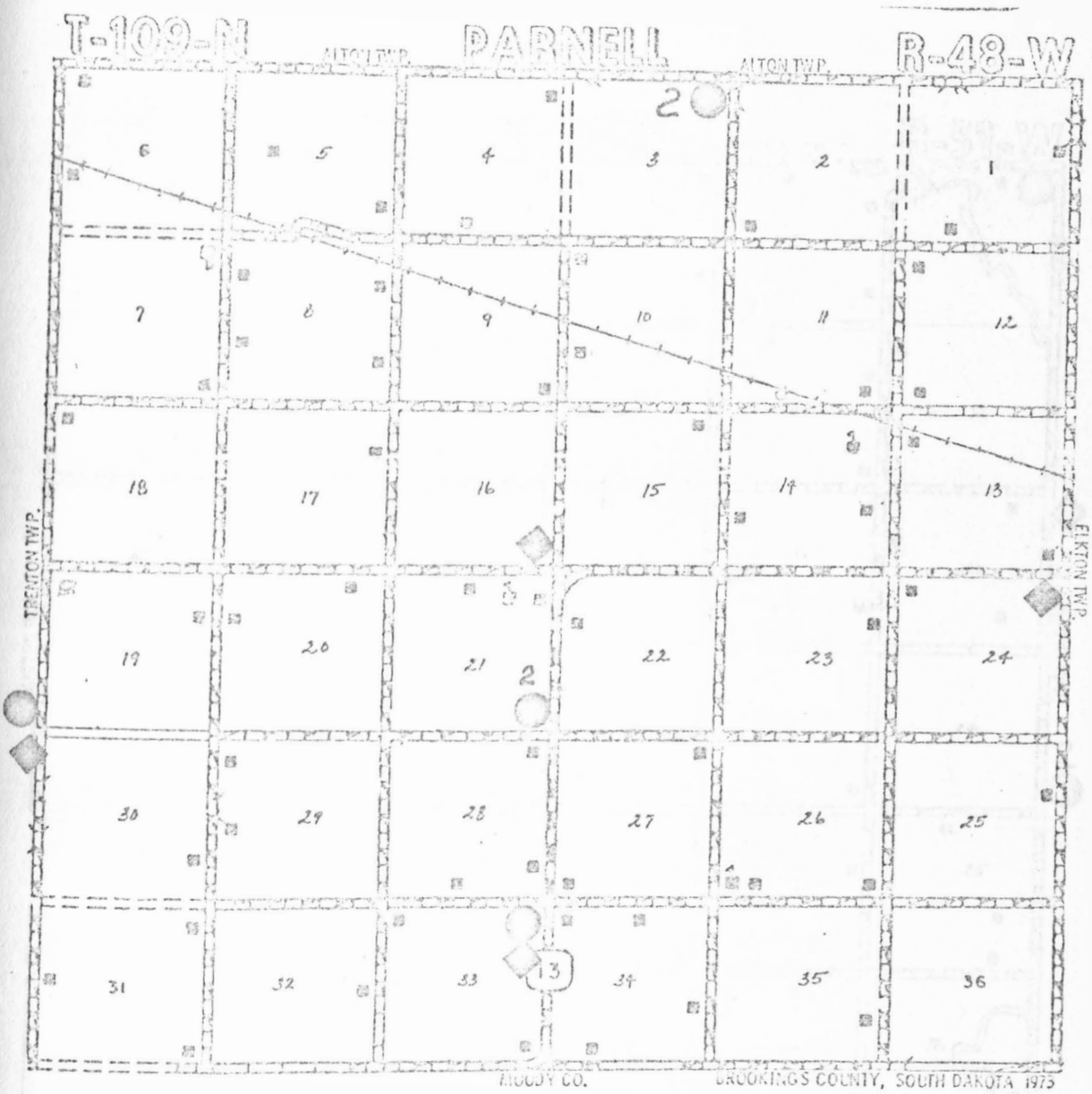

Figure C-16: Container Site Locations, Parnell Township.

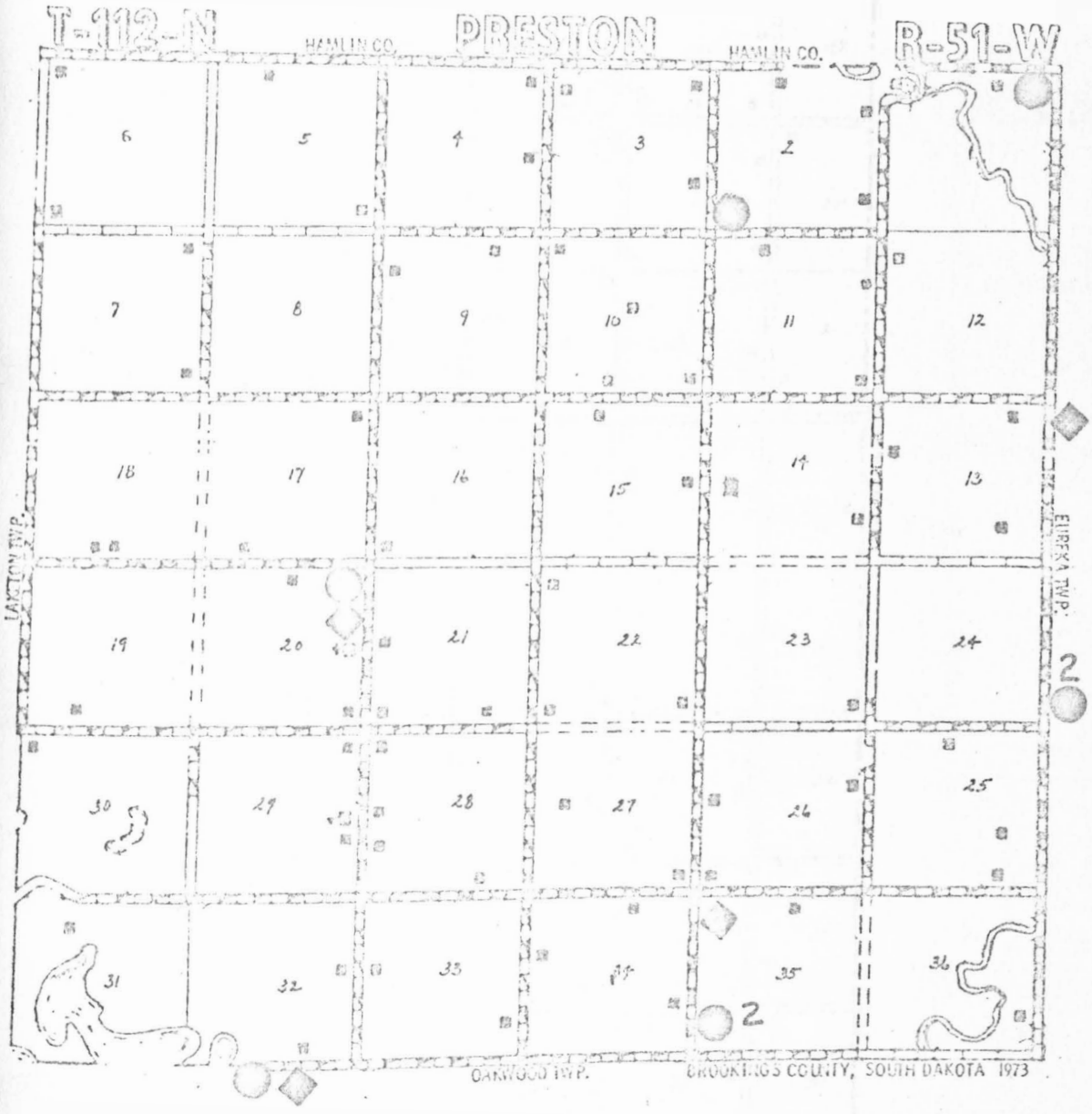

Figure C-17: Container Site Locations, Preston Township.

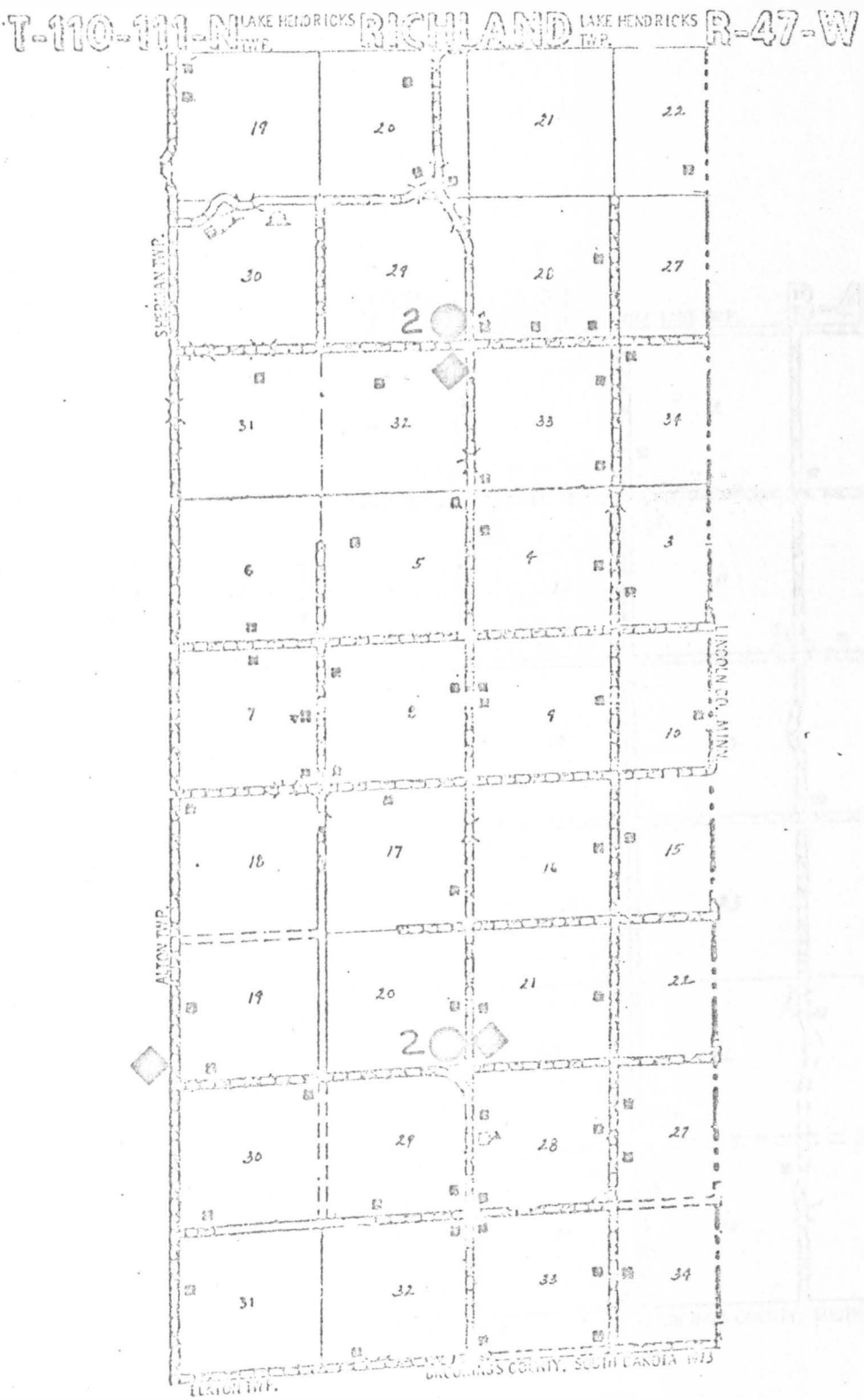

Figure C-18: Container Site Locations, Richland Township.

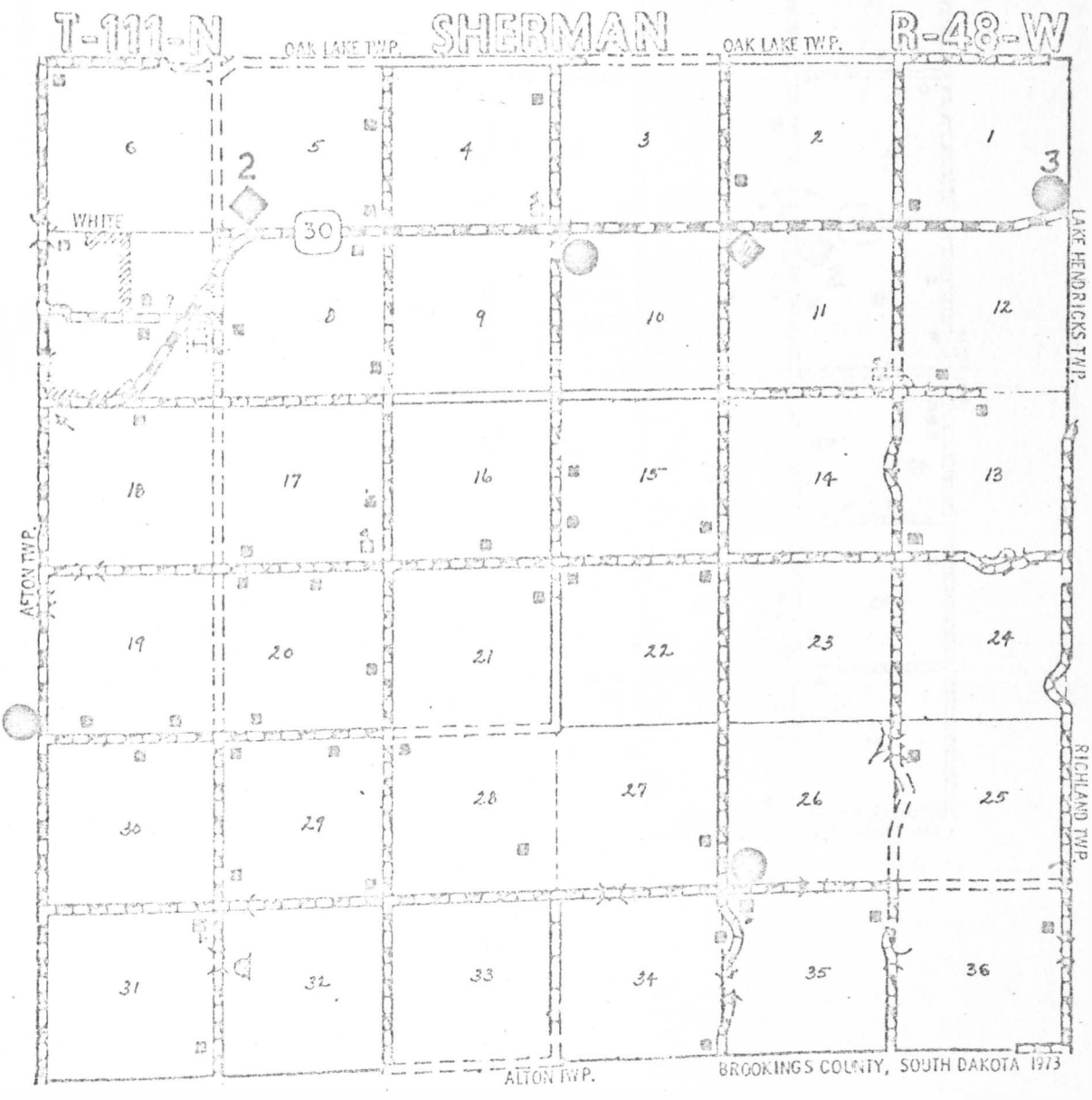

Figure C-19: Container Site Locations, Sherman Township.

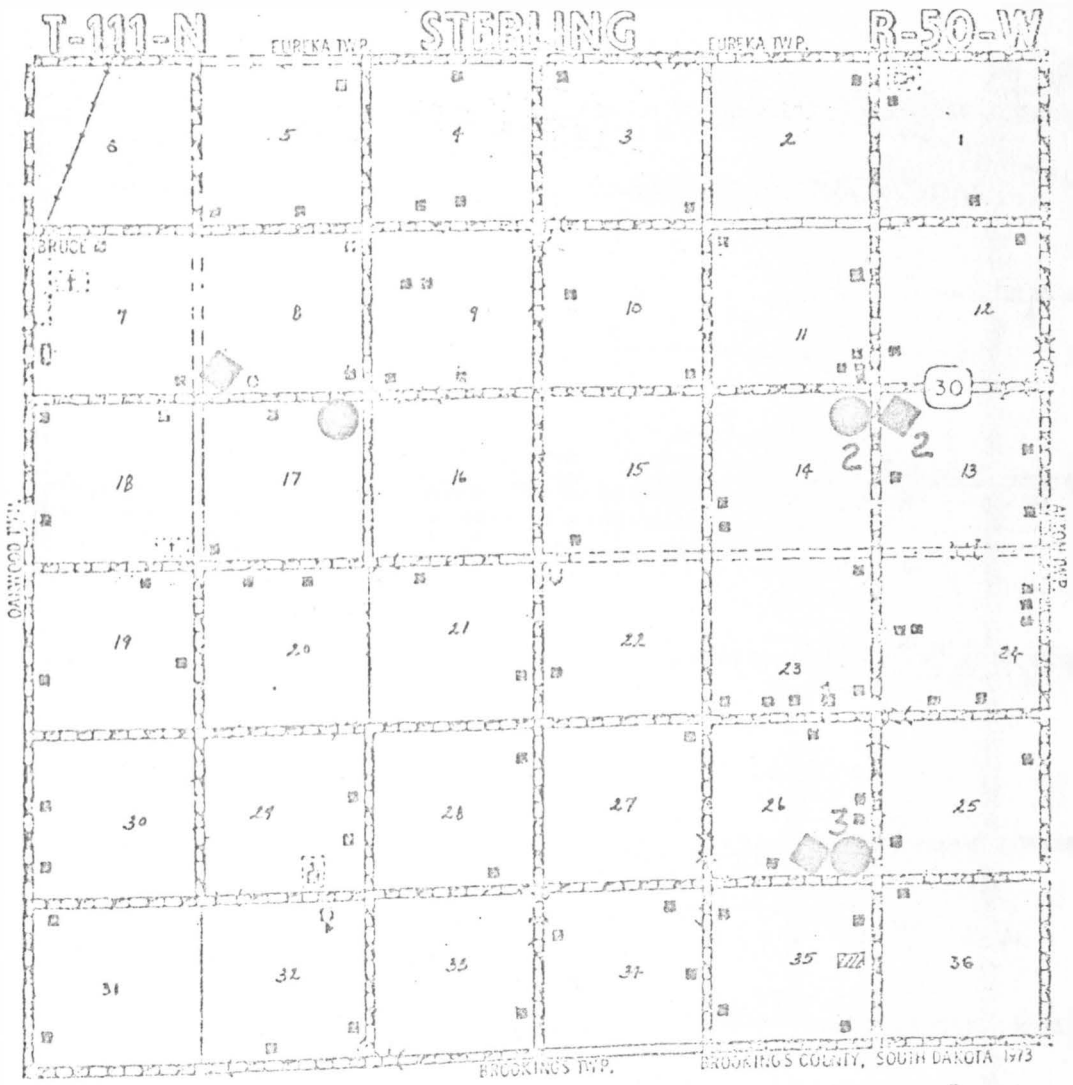

Figure C-20: Container Site Locations, Sterling Township.

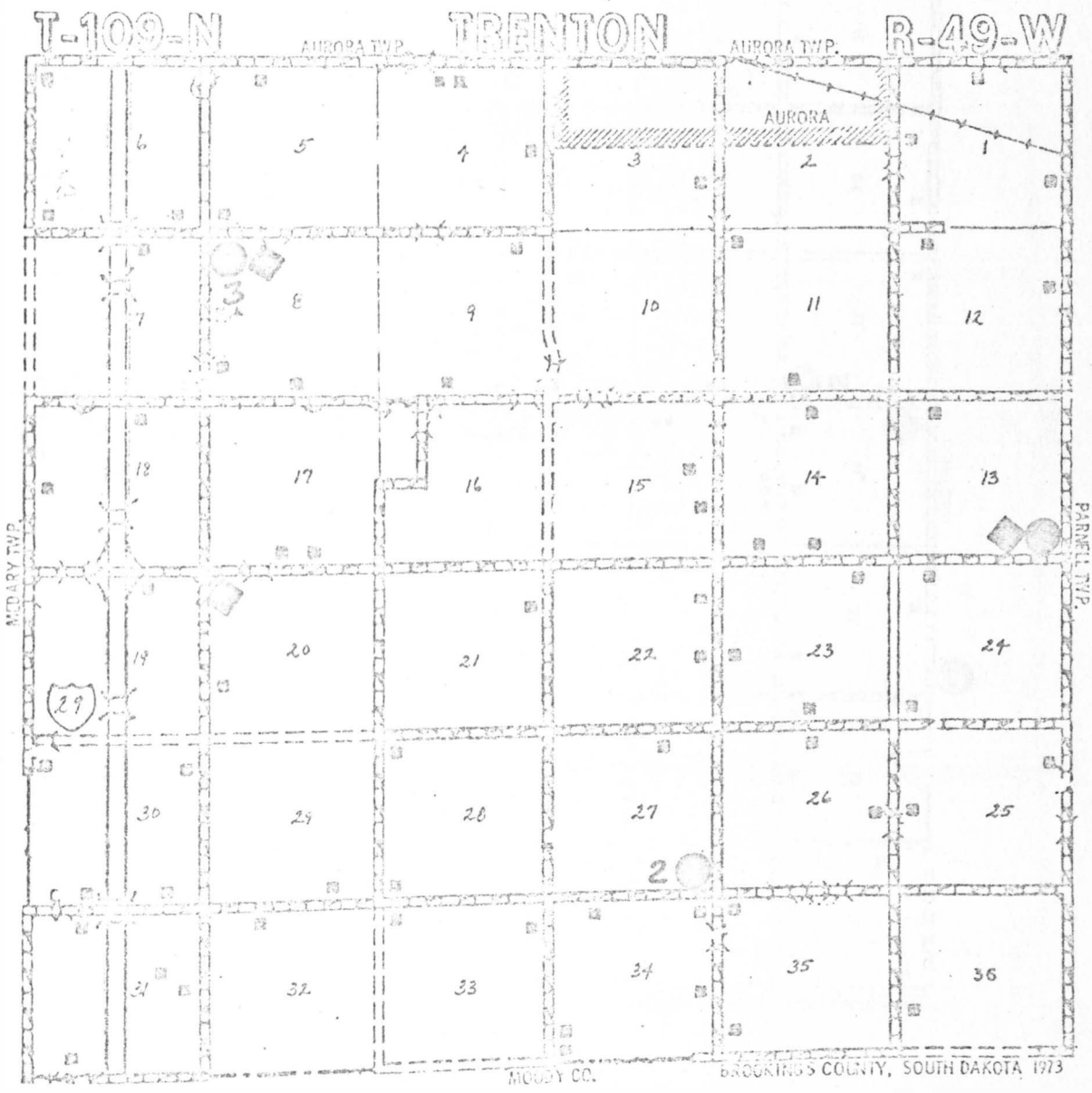

Figure C-21: Container Site Locations, Trenton Township.

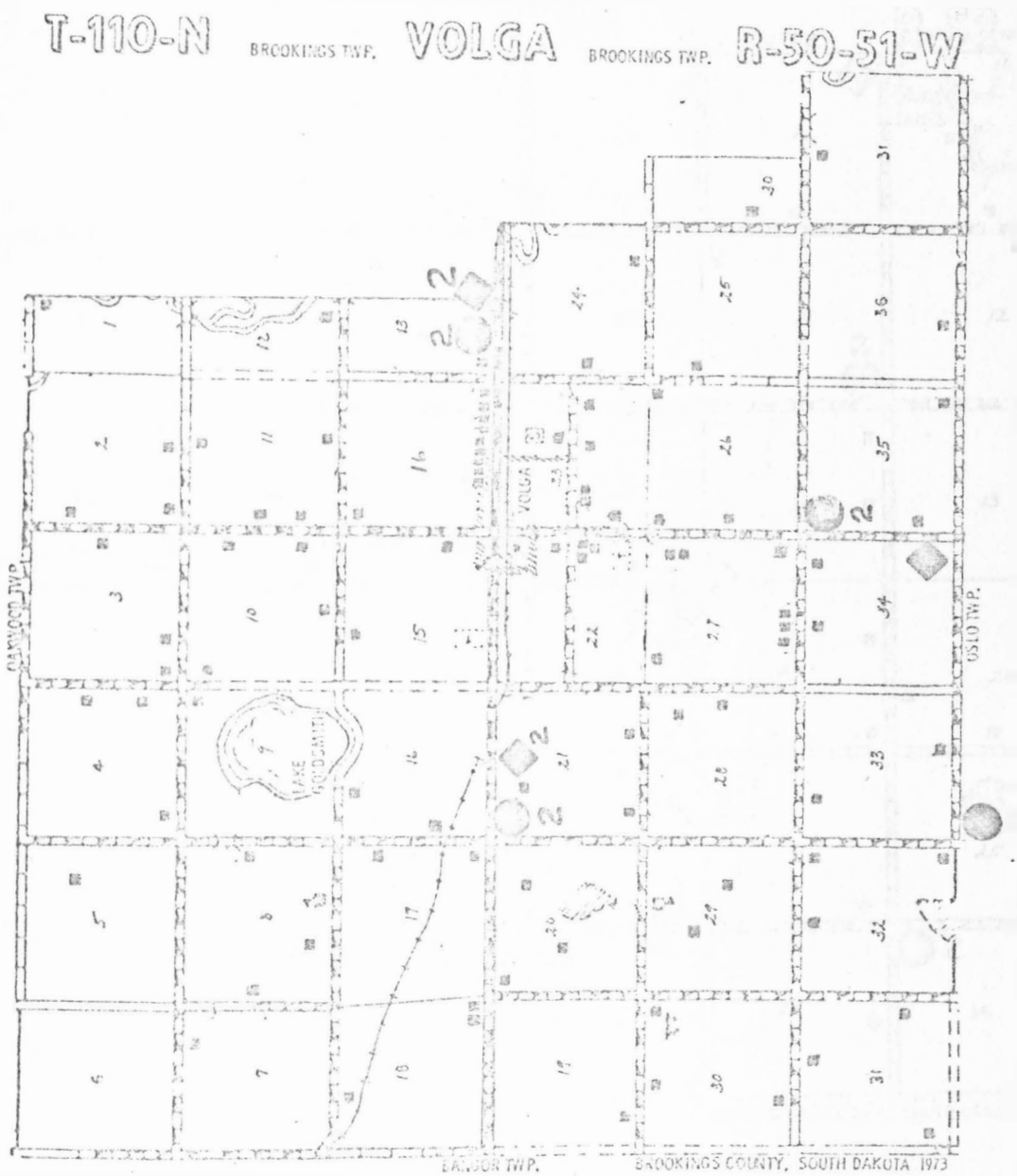

Figure C-22: Container Site Locations, Volga Township.

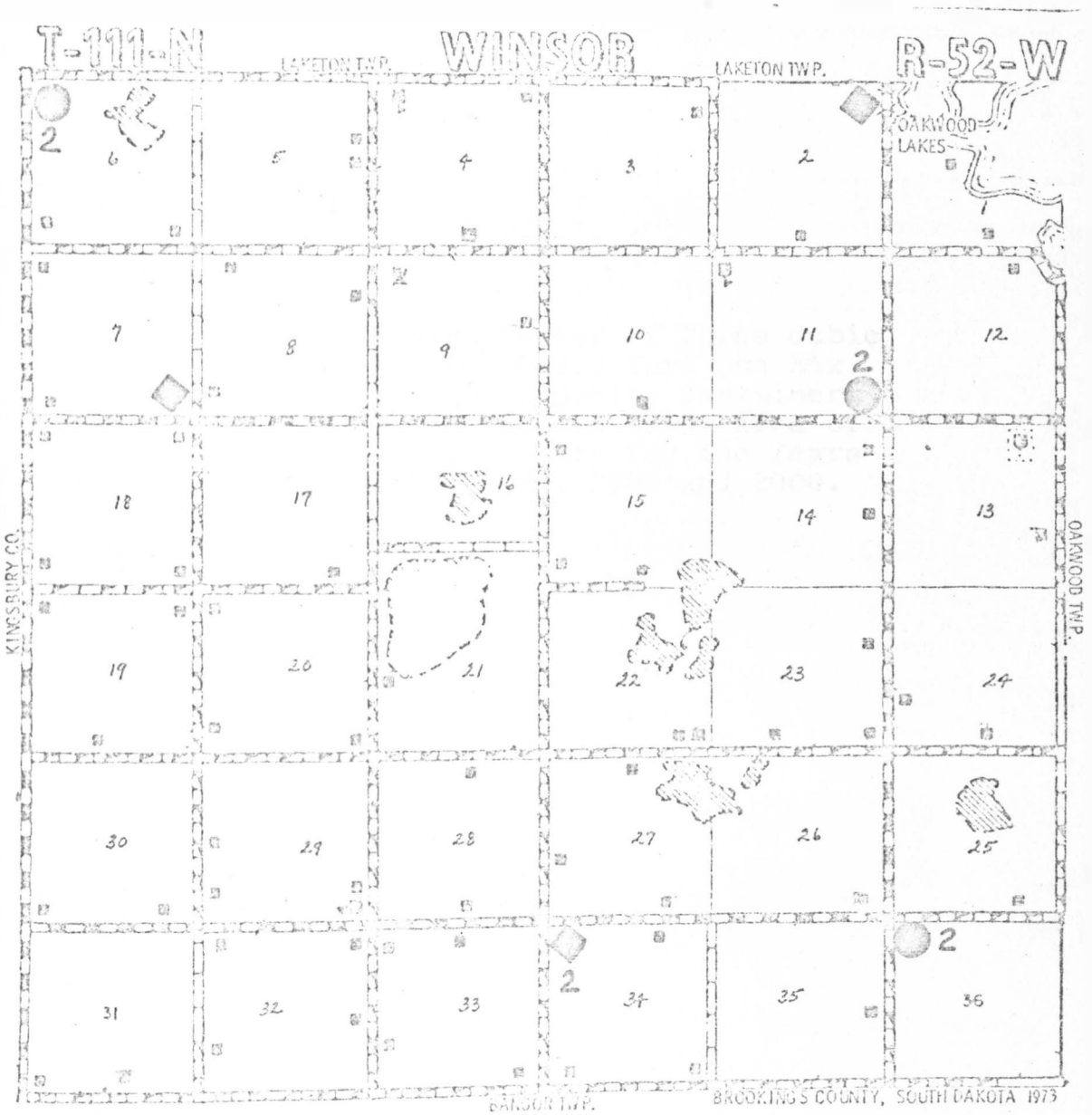

Figure C-23: Container Site Locations, Winsor Township.

APPENDIX D

Estimated Number of Three Cubic Yard, Four Cubic Yard and Six Cubic Yard Capacity Containers Required for the Rural Area of Brookings County for the Years of 1970, 1980, 1990 and 2000.

Table D-1: Number of Containers Required for Rural Areas of Brookings County, 1970.

Township	Loose Volume C.Y./ Week	Number of Containers * 3 C.Y. Size	4 C.Y. Size	6 C.Y. Size
Afton	18.8	6.5	4.5	3.0
Alton	20.6	7.0	5.0	3.5
Argo	16.9	5.5	4.0	3.0
Aurora	23.2	8.0	6.0	4.0
Bangor	18.7	6.0	4.5	3.0
Brookings	31.8	10.5	8.0	5.5
Elkton	11.8	4.0	3.0	2.0
Eureka	17.2	6.0	4.5	3.0
Lake Hendricks	14.8	5.0	3.5	2.5
Laketon	16.2	5.5	4.0	2.5
Lake Sinai	18.1	6.0	4.5	3.0
Medary	40.6	13.5	10.0	7.0
Oak Lake	18.6	6.0	4.5	3.0
Oakwood	18.1	6.0	4.5	3.0
Oslo	20.8	7.0	5.0	3.5
Parnell	18.2	6.0	4.5	3.0
Preston	19.1	6.5	5.0	3.0
Richland	16.2	5.5	4.0	2.5
Sherman	14.2	4.5	3.5	2.5
Sterling	24.3	8.0	6.0	4.0
Trenton	21.8	7.5	5.5	3.5
Volga	25.7	8.5	6.5	4.5
Winsor	20.5	7.0	5.0	3.5
Total Rural	466.4	156.0	115.5	78.0

* Nearest 0.5 Container

Table D-2: Number of Containers Required for Rural Areas of Brookings County, 1980.

Township	Loose Volume C.Y./ Week	Number of Containers * 3 C.Y. Size	4 C.Y. Size	6 C.Y. Size
Afton	18.7	6.0	4.5	3.0
Alton	20.7	7.0	5.0	3.5
Argo	16.9	5.5	4.0	3.0
Aurora	23.3	8.0	6.0	4.0
Bangor	18.8	6.5	4.5	3.0
Brookings	41.1	13.5	10.5	7.0
Elkton	11.9	4.0	3.0	2.0
Eureka	17.3	6.0	4.5	3.0
Lake Hendricks	14.9	5.0	3.5	2.5
Laketon	16.3	5.5	4.0	2.5
Lake Sinai	18.1	6.0	4.5	3.0
Medary	52.4	17.5	13.0	8.5
Oak Lake	18.7	6.0	4.5	3.0
Oakwood	18.1	6.0	4.5	3.0
Oslo	20.9	7.0	5.0	3.5
Parnell	18.2	6.0	4.5	3.0
Preston	19.2	6.5	5.0	3.0
Richland	16.3	5.5	4.0	2.5
Sherman	14.3	5.0	3.5	2.5
Sterling	24.4	8.0	6.0	4.0
Trenton	21.9	7.5	5.5	3.5
Volga	26.0	8.5	6.5	4.5
Winsor	20.6	7.0	5.0	3.5
Total Rural	489.0	163.5	121.0	81.0

* Nearest 0.5 Container

Table D-3: Number of Containers Required for Rural Areas of Brookings County, 1990.

Township	Loose Volume C.Y./ Week	Number of Containers * 3 C.Y. Size	4 C.Y. Size	6 C.Y. Size
Afton	18.1	6.0	4.5	3.0
Alton	20.0	6.5	5.0	3.5
Argo	16.4	5.5	4.0	2.5
Aurora	22.5	7.5	5.5	4.0
Bangor	18.2	6.0	4.5	3.0
Brookings	52.9	17.5	13.0	9.0
Elkton	11.5	4.0	3.0	2.0
Eureka	16.7	5.5	4.0	3.0
Lake Hendricks	14.4	5.0	3.5	2.5
Laketon	15.7	5.0	4.0	2.5
Lake Sinai	17.5	6.0	4.5	3.0
Medary	67.5	22.5	17.0	11.5
Oak Lake	18.1	6.0	4.5	3.0
Oakwood	17.5	6.0	4.5	3.0
Oslo	20.2	6.5	5.0	3.5
Parnell	17.6	6.0	4.5	3.0
Preston	18.6	6.0	4.5	3.0
Richland	15.7	5.0	4.0	2.5
Sherman	13.8	4.5	3.5	2.5
Sterling	23.6	8.0	6.0	4.0
Trenton	21.2	7.0	5.5	3.5
Volga	25.1	8.5	6.5	4.0
Winsor	20.0	6.5	5.0	3.5
Total Rural	502.8	167.0	126.0	85.0

* Nearest 0.5 Container

Table D-4: Number of Containers Required for Rural Areas of Brookings County, 2000.

Township	Loose Volume C.Y./ Week	Number of Containers * 3 C.Y. Size	4 C.Y. Size	6 C.Y. Size
Afton	17.0	5.5	4.5	3.0
Alton	18.9	6.5	4.5	3.0
Argo	15.4	5.0	4.0	2.5
Aurora	21.2	7.0	5.5	3.5
Bangor	17.2	5.5	4.5	3.0
Brookings	68.0	22.5	17.0	11.5
Elkton	10.8	3.5	2.5	2.0
Eureka	15.8	5.5	4.0	2.5
Lake Hendricks	13.6	4.5	3.5	2.5
Laketon	14.8	5.0	3.5	2.5
Lake Sinai	16.5	5.5	4.0	3.0
Medary	86.4	29.0	21.5	14.5
Oak Lake	17.0	5.5	4.5	3.0
Oakwood	16.5	5.5	4.0	3.0
Oslo	19.0	6.5	5.0	3.0
Parnell	16.5	5.5	4.0	3.0
Preston	17.5	6.0	4.5	3.0
Richland	14.8	5.0	3.5	2.5
Sherman	13.1	4.5	3.5	2.0
Sterling	22.3	7.5	5.5	3.5
Trenton	20.0	6.5	5.0	3.5
Volga	23.7	8.0	6.0	4.0
Winsor	18.9	6.5	4.5	3.0
Total Rural	514.9	172.0	129.0	87.0

* Nearest 0.5 Container

APPENDIX E

Appendix E contains the detailed cost estimate of the rural collection system. The unit costs used are based on current prices available. The container site costs were spread over a twenty year period, as this is a common time period for bonds or other funding. Equipment costs were spread over a much shorter time due to the comparative short service life of machinery.

Table E-1: Estimate of Rural Collection Site Acquisition and Development Cost.

Item	Cost
Cost per Rural Collection Site (Typical)	
Land Acquisition: One Acre @ $1,000 per Acre	$ 1,000
Site Grading: Scraper and Blade, 8 Hours @ $75 per Hour	600
Fencing: 500 Feet @ $0.50 per Foot	250
Surfacing: Gravel, 210 Tons @ $1.25 per Ton	262
Or Asphalt Surfacing, 956 Square Yards @ $3.00 per Square Yard	2,868
Total Cost per Site, Gravel Surface	2,112
Total Cost per Site, Asphalt Surface	4,718
Total Cost, 76 Gravel Surfaced Sites	160,512
Total Cost, 66 Gravel Surfaced Sites	139,392
Total Cost, 76 Asphalt Surfaced Sites	358,568
Total Cost, 66 Asphalt Surfaced Sites	311,388

Table E-2: Estimated Cost per Year for Sites

Item	Annual Cost 4 C.Y. Route	Annual Cost 6 C.Y. Route
Land cost per year, Purchase cost spread over a 20 year period.	$17,928	$15,569
Interest on investment at 5%	8,964	7,784
Total	$26,892	$23,353

Table E-3: Estimated Costs of Equipment Required for Rural Collection System.

Item			Cost
Side-loader, 24 Cubic Yard Packer Truck			
	Truck	$16,000	
	Packer Body	9,000	
	Total		$25,000
Front-loader, 24 Cubic Yard Packer Truck			
	Truck	$17,000	
	Packer Body	13,000	
	Total		30,000
Containers: 3 Cubic Yard Capacity		$200	
4 Cubic Yard Capacity		250	
6 Cubic Yard Capacity		350	
For 1970 Quantities:			
4 C.Y. Containers, 130 @ $250			32,500
6 C.Y. Containers, 87 @ $350			30,450

Table E-4: Detail of Operating Costs of Rural Collection System.

Item		Cost
Fuel: $0.55 per Gallon, 3.5 Miles per Gallon		$0.1571
Oil (12):		0.0004
Tires (12):		0.0617
Repair and Maintenance (12):		0.1500
Total Cost per Mile (Side-loader)		$0.3692
	Or	$0.37
Total Cost per Mile (Front-loader)(Extra tires)		$0.38
Four-Cubic Yard Container Routes, 519 Miles per week		
519 x 52 Weeks = 26,988 Miles per Year		
26,988 x $0.37 per Mile		$ 9,986
Six-Cubic Yard Container Routes, 509 Miles per Week		
509 x 52 Weeks = 26,468 Miles per Year		
26,468 x $0.38 per Mile		$10,058

Table E-5: Estimate of Annual Equipment and Site Cost for Rural Collection System.

Item		Annual Cost
Truck:	Five Year Service Life and a Salvage Value of $5,000 to $6,000.	
	Side-loader: $25,000-5,000= 20,000	
	$20,000/5 Years = $4,000 per Year	$ 4,000
	Interest: $20,000/2 x 7%	700
	Front-loader: $30,000-6,000= 24,000	
	$24,000/5 Years = $4,800 per Year	4,800
	Interest: $24,000/2 x 7%	840
Containers:	Service life of 8 Years and No Salvage Value.	
	Four-Cubic Yard Containers	
	$32,500/8 Years =	4,062
	$32,500/2 x 7% =	1,138
	Six-Cubic Yard Containers	
	$30,459/8 Years =	3,806
	$30,450/2 x 7% =	1,066
Garage:	24 feet x 48 feet = 1152 Square Feet	
	1152 Square Feet @ $6.00 per Square Foot = $6,912. $6,912/20 Year Life =	346

Table E-6: Operating Cost of Rural Collection System

Item	Annual Cost Side Loader	Front Loader
Driver Salary per Year	$ 7,000	$ 7,200
Loader or Collector Salary per Year	6,500	-
Social Security, Insurance, Etc.	3,375	1,800
Tax, Truck Insurance, Etc. (12)	1,165	2,025
Total	$18,790	$11,025